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Evaluation of Operation and Maintenance Factors Limiting Biological Wastewater Treatment Plant Performance

Gannett Fleming Corddry and Carpenter, Inc, Harrisburg, PA

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16. ABSTRACT

The purposes of this research study were to evaluate operational and maintenance programs at municipal biological wastewater treatment facilities; identify all the deficiencies in the areas of design, operation, maintenance and administration; and to determine how the deficiencies could be overcome and operations could be improved in order to upgrade plant performance to meet standards. Conclusions and recommendations are based on 1/2-to-1-day site visits made to 120 facilities and 3-to5-day comprehensive evaluations conducted at 30 facilities. Of 70 potential problem areas evaluated, the ten highest ranked, based on frequency of occurrence and severity of impact were operator application of treatment concepts and testing to process control, infiltration/inflow, process control testing procedures, adequacy of O&M manual, industrial loading, training, hydraulic loading, treatment understanding, process controllability, and sludge treatment.

end

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EVALUATION OF OPERATION AND MAINTENANCE FACTORS LIMITING BIOLOGICAL WASTEWATER TREATMENT PLANT PERFORMANCE

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of theAmerican people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

In the report documentation from comprehensive biological treatment plant evaluations establishes cause and effect relationships for poor plant performance and the top ten factors causing poor performance are identified. A procedure, called a Composite Correction Program, was developed and implemented to improve plant performance. Unlike existing programs, the CCP approach identifies all factors limiting plant performance at individual facilities and solutions to all the problems are implemented. Results show that many plants formerly not in compliance are performing to meet their design standards and permit requirements without the need for major construction.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

PREFACE

This document sets forth findings, conclusions, and recommendations as a result of a two-year examination of selected biological wastewater treatment facilities. The purpose of this investigation is to evaluate operational and maintenance programs at biological facilities, identify deficiencies in such programs, and determine where improvements in operation and maintenance will upgrade plant performance to the point that secondary treatment is consistently achieved. Two separate contracts were awarded by the U. S. Environmental Protection Agency for performance of investigations in the eastern and western sectors of the country, respectively. The contract for the eastern study area, which included Pennsylvania, Maryland, Virginia, and West Virginia, was awarded to Gannett Fleming Corddry and Carpenter, Inc., Harrisburg, Pennsylvania. M&I, Inc., Fort Collins, Colorado, was responsible for performing these investigations in Colorado, Iowa, Montana, Nebraska, South Dakota, Utah, and Wyoming.

From the inception of the study, it was apparent that both contractors would need to follow the same general guidelines if the findings and recommendations resulting from the two studies were ultimately to be compared. Criteria for selection of candidate plants, field investigative practices, data compilation and analysis, and reporting procedures had to be as uniform as possible. However, it was not the intent of EPA, nor the contractors, to make one study a duplicate of the other. Region-specific conditions made complete uniformity of plant selection criteria impractical. Although plant selection guidelines with respect to type of treatment, plant capacity, and plant upgrading or enlargement were relatively uniform for both regional studies, the issue of infiltration/inflow was treated differently by each contractor. As a result of geologic and climatic conditions in those states comprising the eastern contractor's study area, infiltration/inflow in varying degree is a widely existent phenomenon. Exclusion of a candidate plant from this study base for that reason alone was not felt to be in the best interests of the study, since many plants in the eastern region must be operated, and will continue to be operated, with infiltration/inflow in the plant influent. This infiltration/inflow was a problem identified at several sites in the eastern study area. Such was not the case for the studies performed in the western region, where excessive infiltration/inflow was a criterion for rejection of a plant as a study site. The investigations under the two contracts were performed independently; yet in some respects the conclusions developed from the two studies were similar. Both contractors reported that operational problems had a greater adverse impact on plant performance than did design deficiencies. Furthermore, lack of application of biological process control principles, inadequate process monitoring, no technical guidance, inadequate training, and lack of a comprehensive operations manual, were found to be the principal causes of performance problems in both study regions.

Accordingly, corrective actions as recommended by both contractors address the matter of improving process control through instruction and application of process testing and control theory.

In summary, the objectives and methods of the eastern and western regional studies were parallel to the extent possible under constraints imposed by local physical conditions. Findings and conclusions presented in each contractor's report were arrived at independently. The similarity in conclusions of both studies indicates that the nature of current operational problems is not related to treatment plant locality. Rather, the problems are fundamental and involve the biological principles governing wastewater treatment processes.

EXECUTIVE SUMMARY

Previous surveys conducted by the U. S. Environmental Protection Agency have demonstrated that over half of the secondary treatment plants in this country are not producing an effluent in compliance with the definition of secondary treatment. Since, on the surface, most of these plants appeared to be adequately designed for their respective organic and hydraulic loadings, these surveys led to the conclusion that the performance of many plants could be upgraded through improvement of operation and maintenance techniques. In July 1975, Gannett Fleming Corddry and Carpenter, Inc. (GFCC), was retained by the EPA to study operation and maintenance programs at selected biological treatment plants in the eastern United States. The overall objective of the 24-month study was to identify and evaluate factors adversely affecting treatment plant performance. By so doing it was felt that correction programs, specifically aimed at ameliorating the identified major problem conditions at each plant could be developed and that plant performance could be upgraded without the need for major capital improvements.

The scope of this investigation was limited to facilities under the jurisdiction of EPA Region III. GFCC (with the assistance of the Chief of the Municipal Permit Programs Branch) contacted the various state agencies within Region III responsible for water pollution control. These agencies were requested to identify candidate treatment facilities, meeting the following criteria:

1. Plants must incorporate a biological treatment process as the basic method of wastewater treatment.
2. Plants should have a history of inadequate performance as measured by effluent quality.
3. Hydraulic capacities of plants should range from 1 to 5 mgd.
4. Plants should not be hydraulically or organically overloaded to any great extent.
5. No enforcement action should be presently under way against the municipality or authority involved.

The treatment plant lists as submitted by the various state agencies were then reviewed, and plants which did not conform to one or more of the selection criteria were deleted. For those that did meet criteria, arrangements were made for study personnel to conduct a site visit. The maximum duration of such visits was one day. Such site visits were conducted at 120 facilities during the course of the investigation. During each site visit, various data were obtained including process flow sheets, influent and effluent wastewater

characteristics, staff size, plant laboratory characteristics, condition of equipment, discharge permit criteria, and other information made available by the superintendent at the time of the site visit. In addition, the plant operating personnel were questioned relative to problems interfering with plant operations.

From those plants visited, 30 were selected for more comprehensive "preliminary evaluation" studies, generally ranging from 3 to 5 days per plant. Generally, the basis for selecting a plant for study under the preliminary evaluation phase was the apparent predominance of operation and maintenance related problems, rather than design inadequacies. Evidence of inadequate staffing, process control deficiencies, improper maintenance, and insufficient funding was noted during the site visits. Also noted were major design deficiencies that could interfere with plant operability. Occasionally, plants were selected for study under the preliminary evaluation phase on the basis of employing nontypical treatment processes, in order to cover as many biological treatment processes as possible under the study. As originally envisioned, the presence of infiltration/inflow problems at the facility was to be justification for eliminating a plant as a preliminary evaluation candidate. However, infiltration/inflow is a widespread problem in the geographical area examined under this contract, and exclusion of a candidate plant for this reason alone was found not to be practical since many plants with significant operating problems would not have been eligible for further study. During each preliminary evaluation, the most recent year's operating records were obtained, sampling and analysis of influent, effluent, and interprocess flows were conducted, and detailed budgetary information was obtained. In addition, operating personnel were interviewed extensively concerning many aspects of operations. Reports covering findings and conclusions for each preliminary evaluation were prepared and submitted to EPA.

One treatment plant, a 4.0 mgd complete mix activated sludge facility, was the subject of an in-depth special study of about 3 months duration. The purpose of the special study was to develop a control strategy for the sludge bulking problem at the plant. Sludge bulking, in varied degrees, had been identified under the preliminary evaluation phase as a major problem at many activated sludge plants. Very little success in long-term alleviation of the problem has been reported. This appears to be due in large measure to the fact that in most cases the specific cause of the problem was not identified. The special study was designed to identify the cause of the bulking problem, and determine a method of eliminating the cause, and therefore, increase the likelihood of a successful control program.

Data collected during each of the 3 project phases (site visit, preliminary evaluation, and special study) resulted in conclusions as summarized in the following paragraphs. The site visit phase included a wide data base with limited depth of investigations. Conclusions, therefore, are of a broad and general nature. Conclusions forthcoming from the preliminary evaluation are considerably more detailed with respect to specific process problems and O&M programs. Conclusions from the special study relate specifically to the problem of sludge bulking.

The 120 site visits resulted in data that suggested several trends or relationships between treatment plant size or process type and various operational or administrative characteristics. Observations from the site visit phase included:

1. Treatment plants serving the smaller populations tend to employ extended aeration, contact-stabilization, or trickling filter processes. Large populations tend to be served by conventional activated sludge plants.

2. Sixteen percent of all plants studied handle a high industrial waste load. Thirty percent of the larger (10 mgd or larger) plants receive high industrial waste loads. High industrial waste loads normally resulted in a total plant overload and reduced plant efficiency. There is no apparent correlation between size or type of facility and impact of industrial waste on operation.

3. Forty-three percent of plants studied experience operating problems as a result of receiving excessive volumes of infiltration/inflow. There is no apparent correlation between size or type of facility and impact of infiltration/inflow on operation.

4. Plants of greater than 5.0 mgd design capacity make significantly greater use of their laboratories through both process control testing and performance testing than do those less than 5.0 mgd. Generally, the laboratories in larger plants are better equipped and staffed.

5. Greater degree of process control is exercised in larger plants (>5.0 mgd) than in smaller plants. Although somewhat greater controllability is built into these facilities, the presence of knowledgeable operators is the principal reason for the degree of control.

6. Inadequate process control impacts activated sludge plants more severely than trickling filter plants.

7. Adequacy of maintenance programs shows a positive correlation with size of facility.

8. On the average, the large plants contain a greater percentage of new equipment than do the smaller plants, since most large facilities tend to be better maintained and have more flexible operating budgets, thus permitting timely replacement of equipment. Smaller plants are frequently required to "make do" when equipment fails.

9. Larger plants have significantly greater unit process backup capability. Process type does not affect backup capability.

10. Larger plants have better preventive maintenance programs than do the smaller facilities. The extent of preventive maintenance programs is not related to process type.

11. Technical references are considerably more complete at the larger plants. These include O&M manuals and literature related to specific items of equipment.

12. Seventy-one percent of plants greater than 5 mgd design capacity have auxiliary power provisions, while only 40 percent of those less than 5 mgd capacity have such provisions.

In general the site visit data indicated that there is a large degree of variation among treatment plants in such areas as level of staff training, process control, age or condition of equipment, and maintenance or housekeeping procedures.

During the preliminary evaluation phase, the degree of impact of identified problem areas on plant performance was assessed. In conducting each preliminary evaluation, the major areas that were investigated in detail included: unit process performance and design adequacy, operational procedures and support facilities (O&M manuals, laboratory, etc.), maintenance programs, and administrative aspects (staffing and budget). A Weighting and Ranking Table was prepared whereby deficiencies and problems at each of the 30 plants studied under the preliminary evaluation phase were reported. This table permitted quantitative weighing of the problems, followed by a ranking of the highest weighted problems. In all, 70 potential problem areas were addressed at each facility. The 10 most frequently encountered problems were identified and ranked and are listed in decreasing order of severity as follows:

1. Operator application of treatment concepts and testing to process control.
2. Infiltration/inflow
3. Process control testing procedures
4. Adequacy of O&M manual
5. Industrial loading
6. Training
7. Hydraulic loading
8. Treatment understanding
9. Process controllability
10. Sludge treatment

As the above ranking list indicates, inadequate plant performance is a function of both specific design problems (loadings and processes) and operational deficiencies. However, the major conclusion of the preliminary evaluation phase is that proper biological process control is not being practiced at most treatment plants. This situation is partially due to inadequate operator training. In many cases, however, it was found that operators with a good knowledge of biological treatment concepts are not controlling their systems according to those concepts, indicating that the importance of process control is apparently not fully appreciated.

In looking into the administrative aspects of treatment plant operation, it was found that a significant number of plants were understaffed. When compared against EPA staffing guidelines, over 50 percent of the plants studied had staffs smaller than the recommended number. In many cases the adverse impact of the small staff is not readily apparent, since buildings, equipment, and grounds appear to be generally well maintained. However, this may simply mean that manpower that could be used for process control is being diverted to maintenance duties. Also, an indication of understaffing on the basis of EPA guidelines does not necessarily mean these plants are not staffed adequately. Rather, the guidelines themselves may be inaccurate, or for a particular facility a relationship between staffing and plant performance is not presently identifiable. Examination of the O&M budgets for the 30 treatment plants indicated that the level of funding in most cases is comparable with the national average for treatment plants of similar type and size. However, there is reason to believe that upgrading the staffing and salary segment of the average wastewater treatment budget would result in improved plant performance. This is especially true for the smaller (<5 mgd) treatment systems.

The final study phase of the project consisted of a detailed investigation to identify the cause of sludge bulking at a special study plant and to recommend physical or operational changes to eliminate the problem. The study site was an activated sludge plant with flexibility and process control designed into the system. However, since start-up, process control was virtually impossible as a result of bulking sludge. The bulking problem has limited return and wasting rates due to the dispersed nature of the sludge in the secondary clarifier. Thus, these important operational parameters could not be adjusted to control the process F/M ratio and mean cell residence time. Previous attempts to "operate out of bulking" by such methods as shifting from complete mix to contact stabilization had met with temporary, or no, success.

The special study was designed to illustrate a more scientific approach to be taken to solve the bulking problem. Using samples of the mixed liquor, the specific filamentous bacteria causing the settling problem were isolated and identified. *Thiothrix* was found to be the major problem organism. Knowing the environmental conditions favoring the proliferation of *Thiothrix*, sources of high sulfide concentration were sought. It was found that design deficiencies in the sludge removal equipment in the final clarifiers caused excessive sludge detention in certain areas of the clarifier bottoms. Extremely high sulfide concentrations were measured in these areas. The propensity for high sulfide concentrations to stimulate the growth of *Thiothrix* has been documented in the literature. Consequently, recommendations were made to alter the clarifier sludge removal systems.

During the site visit and preliminary evaluation phases, it was observed that bulking causes poor effluent quality in many activated sludge plants of all types. The special study points out that the cause of the problem is site specific: each instance must be studied, the cause identified, then solutions to resolve the problem can be determined and implemented to correct the problem. Nonspecific approaches, such as additions of chemical oxidants to the aeration system or the return sludge flow, often treat the effect, rather than the cause, of the process problem. Hence, such methods are likely to provide only temporary relief and, furthermore, represent an operating cost that may not be necessary.

This report was submitted in partial fulfillment of Contract No. 68-03-2223 by Gannett Fleming Corddry and Carpenter, Inc., Harrisburg, Pennsylvania, under the sponsorship of the Environmental Protection Agency. Work described in this report was accomplished during the period from June, 1975 to December, 1977.

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SECTION 1

INTRODUCTION

The Federal Water Pollution Control Act Amendments of 1972 established specific goals for controlling wastewater discharges to meet certain water quality objectives. Achieving these goals will require significant capital expenditures for construction of new wastewater treatment plants and will also require all treatment plants, both new and existing, to be operated efficiently and effectively. Proper operation of new and modified plants, and improved operations of existing ones, are essential if water quality goals are to be met. Optimization of operation is critical to realizing the maximum return on the sizable investment being made for sophisticated pollution control systems.

Operation and maintenance surveys conducted in accordance with Section 210 of the Act are included in the annual Clean Water Report to Congress. In 1973 and 1974, the years preceding this study, these surveys showed that about one-third of all treatment plants constructed with federal grant assistance were not operating at the design efficiency level when the plants were inspected. These surveys showed severe deficiencies in the areas of operation and maintenance, manpower, hydraulic load, laboratory facilities, and testing programs. As a result the plants failed to meet their permit requirements for effluent loadings of biochemical oxygen demand (BOD_5), suspended solids, and settleable solids. These same shortcomings were also perceived by the national and regional offices of the EPA.

This study was conducted to identify and rank the causes of poor performance in biological treatment plants. Performance problems were studied on three levels. One-day site visits were used to screen 120 candidate plants. Thirty of these plants were selected for three- to five-day preliminary evaluations in which various administrative, design, operational, and maintenance factors were examined. At one plant, identified as having a severe filamentous bulking problem, a three-month extended study was made to identify the cause of the bulking and to recommend specific corrective measures. Based on the detailed studies at the preliminary evaluation level, a priority listing of causative factors was developed. These problems represented those areas most frequently identified as requiring application of corrective measures (exclusive of major expenditures for construction) to bring treatment plant performance into compliance with design intent and permit criteria. At each of the thirty plants that was the subject of a three-to-five day intensive study, recommendations to improve performance were made. The impact of implementing these recommendations in terms of reduced pollutant loadings to the environment was assessed.

The project which is discussed in the following pages represents a significant first step in maximizing the return of the national investment in pollution control facilities. There are many well-designed wastewater treatment plants capable of high degrees of pollutant removal now on line, and the number is continually increasing. However, the evidence indicates construction of facilities is only part of the solution. Good operation, maintenance, and administrative programs must be in force or the best of facilities will produce unacceptable effluent. Through projects such as this, areas where operational programs and procedures are weak can be identified. In this manner, programs may be developed to optimize the efficiency of treatment systems which currently have a partially untapped potential.

SECTION 2

CONCLUSIONS

On the basis of the 30 preliminary evaluations conducted in the eastern U. S. study area, treatment plant performance appears to be more limited by operational, maintenance, and administrative shortcomings than by design deficiencies or errors. The more common operational causes of inadequate plant performance were:

1. Wastewater treatment concepts and process testing results were not applied by the operators to control the biological process.
2. To varying degrees, personnel staffing most treatment facilities were familiar with conventional process control techniques, but this knowledge was not effectively applied in practice.
3. At most plants process testing was not performed at a level required for proper monitoring and control. Basic process control parameters such as MLSS, MLVSS, SVI, and F/M were frequently not monitored.
4. Plant laboratory capabilities, including equipment, test procedures, and record keeping, were marginally adequate or inadequate in many cases.
5. O&M manuals were either nonexistent or not comprehensive enough to be of benefit to the plant staff.
6. Most operators had received some sort of training in wastewater treatment technology. However, training programs were general in nature and did not address plant-specific process control or "troubleshooting" techniques.

Design-related limitations on plant performance were also noted during the study, although not be the degree that operational problems were observed. The more frequently encountered design related problems were:

1. Periodic hydraulic overloading as a result of excessive infiltration/inflow was widespread among plants in the study region.
2. Process overloading occurred as a result of industrial waste discharges, typically received by the plant in "slug" loadings.

3. Lack of built-in controllability or flexibility, especially in small package systems, resulted in limited performance potential.

4. Inadequate sludge treatment or disposal capabilities limited the control of sludge wasting and return rates, thereby interfering with the operator's implementation of sound process control strategies.

Maintenance programs and practices were examined at each of the preliminary evaluation sites and findings were as follows:

1. With the exception of spare parts inventories and parts procurement, routine maintenance practices were marginally adequate or better.

2. Housekeeping practices were generally satisfactory. In fact, in many cases it was apparent that greater effort was devoted toward maintaining plant appearance than was expended for obtaining optimal facility performance.

3. Emergency maintenance capabilities, including manpower, parts, and equipment, are adequate at most facilities. However, improved alarm systems and auxiliary power sources are needed.

Administrative deficiencies were occasionally found to be causes of poor plant performance. The following items were specifically noted:

1. Total operating budgets at most of the preliminary evaluation plants were nearly equal to or exceeded a calculated average expenditure for operation and maintenance of plants of similar size and type. However, budgets were frequently too general and disorganized, making it difficult to determine how funds were apportioned.

2. Approximately one-third of the facilities were staffed at a level at least 20 percent less than that recommended by EPA staffing guidelines.

3. In terms of labor categories, the greatest manpower deficiency apparently existed in the area of maintenance. The validity of this observation, however, is dependent on the accuracy with which employee job titles and descriptions at each plant reflect the employee's actual duties.

Over the past few years operational problems have been increasingly recognized as limiting factors to treatment plant performance. As a result programs and literature have been developed to aid the operator in optimizing performance. However, this study indicated that, to date, these programs have had minimal impact on plant operations. According to observations at the study sites, reasons for this minimal impact are as follows:

1. EPA Technology Transfer information and Operation Manuals, while readily available, are not reaching a large percentage of the operators.

2. Process control information presented in training courses and certification programs is not being carried over into the field. It is apparent that operators find it difficult to relate the theoretical information presented in such courses to the specific operating problems at their plants.

3. Operations and troubleshooting seminars presented by EPA are not widely attended by operators.

4. Technical assistance is available through operations consultation groups in some consulting engineering firms, but municipalities rarely take advantage of this on a continuous or regular basis. This is undoubtedly due to cost of such services.

5. O&M manuals as currently prepared do not reflect the input of the plant operating staff, and operators, therefore, often find these manuals difficult to follow. The manuals are seldom used on a day-to-day basis.

As a part of each preliminary evaluation, specific recommendations were set forth for improving plant performance. The primary intent of these recommendations was to set forth nonstructural modifications, addressing areas such as training, process monitoring and control, O&M manual preparation, and budgeting for plant operations. The actual impact of implementing these recommendations is not known. However, on the basis of engineering judgement an estimate of attainable wastewater quality at each plant was developed. On the basis of these estimates, compliance with NPDES permit limitations by the 30 plants would improve from 79 percent to 90 percent for BOD_5 and from 55 percent to 86 percent for suspended solids, strictly as a result of implementing the recommended operational improvements.

SECTION 3

RECOMMENDATIONS

The results of this study show that there is significant potential for improving performance of biological treatment systems through upgrading operation and maintenace practices. The specific areas where operation, maintenance, or administration of wastewater treatment facilities apparently fall short have been discussed in detail. As a result of this study there is little doubt that there are tangible benefits to the environment to be gained through operationally improving the performance of biological treatment plants, and closing the gap between design intent and current effluent quality. Eight specific recommendations are offered toward the ultimate achievement of the above objective.

1. Operator training programs should be expanded and improved to address process control technology and to emphasize the direct impact of continuous process control on effluent quality. Positive step-by-step control strategies should be presented and fully explained. This could be done at state level and tied in with certification programs, or through the federal government's training activities. Also, site-specific training programs should be provided for large or complex treatment systems to provide the operating staffs with a hands-on knowledge of available process control techniques.

2. Positive action should be taken to assure process control is practiced at treatment facilities to optimize performance. An example of such positive action would be regulatory agency monitoring of process control by requiring various process parameters be reported along with the effluent quality parameters now specified in discharge permits.

3. More involvement of consulting engineers and other recognized experts in technical operations assistance should be encouraged and, in some cases, possibly be made a grant eligible cost.

4. During the design stage, more attention should be directed to the treatment plant laboratory, especially at smaller (<5 mgd) facilities. The intent would be to ensure that adequate facilities are provided for effluent process control testing and thorough wastewater characterization.

5. More comprehensive and understandable process control descriptions should be provided to operators by design engineers and technical assistance sources. Such information should be included in the plant operation and maintenance manual, which in turn should reference manuals provided through state and federal government for augmentation and clarification of theory as necessary.

6. Budgeting for operation and maintenance of wastewater treatment facilities must become more organized and needs-sensitive. This is especially true in the case of the smaller (<5 mgd) treatment systems. Higher priority for wastewater treatment in the municipal budget must be established.

7. Mechanisms to attract, and keep, high-caliber operators should be identified and implemented. Included might be higher entry level educational background requirements, higher salaries, increased opportunities for advanced training, and better defined potential for advancement. The status of the treatment plant superintendent as a key public works official must be established.

8. Operability and flexibility should be carefully considered during the design process. This, of course, will do little for existing plants, but may significantly reduce future problems. If possible, the principal operating personnel to be employed at the plant should be retained during the final design stages. Their comments, criticisms, and suggestions should be fully evaluated by the design engineer. Significant future operating problems might thereby be avoided.

The recommendations set forth above are designed to reduce or remove the negative impacts of the priority problem areas identified by this study. Table 1 shows the problem areas which each of the recommendations as offered below will impact.

TABLE 1. IMPACT OF RECOMMENDATIONS ON FREQUENTLY ENCOUNTERED PROBLEMS

	Recommendation							
Problem	1	2	3	4	5	6	7	8
Operator application of concepts and testing to process control	x	x	x		x			
Infiltration/inflow								
Process control testing	x	x	x	x	x			
O&M manual adequacy					x			
Industrial loading								
Training	x		x		x			

TABLE 1 (continued)

	Recommendation							
Problem	1	2	3	4	5	6	7	8
Hydraulic loading								
Treatment understanding	x		x					
Process controllability								x
Sludge treatment								

Finally, this study has answered some questions with regard to where operational programs are weak, and what impact these deficiencies are having on treatment plant performance. However, some questions have not been fully answered, and the advisability of further study is indicated. We, therefore, recommend that the investigations discussed herein be continued to provide a greater data base for further identification of operational, maintenance, and administrative areas, where improvement could result in better levels of treatment plant performance. It is also recommended that certain problems identified during this investigation be studied in greater depth, so that the most effective remedial programs may be evolved. An example is operator training. It has been concluded that the level of training, to which many supervisory operators have been exposed, has not, to date, been implemented in plant operation. The question must be raised relative to why there exists a gap between knowledge of biological treatment principles, and implementation of these principles in process control. A more intensive study of training programs and methods of transferring classroom theory to field application, than could be conducted within the scope of the present investigation, should provide insight into this problem. Another area where further study seems advisable is adequacy of wastewater treatment plant operations funding. It is apparent that some treatment plants are underfunded, and performance suffers as a direct result. However, it is difficult to determine the severity of budget deficiencies, or the specific areas where increased funding would have the greatest positive impact. No standards for comparison to determine budget adequacy on a unit pollutant removal basis exist.

The above are but a few examples where continued and increased study is likely to help in the effort to achieve greater levels of performance from existing treatment facilities. There is little question that much is to be gained through concentrating on improving operational or administrative programs at wastewater treatment facilities. The maximum return on the national investment in pollution control equipment has not yet been realized. Increasing this return requires improvement of operational programs. This objective should be heavily emphasized in research activities for the immediate future.

SECTION 4

RESEARCH APPROACH

In this section the research approach on which this two-year investigation was structured will be described. This discussion will be broken down into two subsections, the first dealing with research approach employed for the site visit phase, and the second dealing with research approach employed for the preliminary evaluation phase. The special study research approach will be presented in the section devoted to that study (Section 7). Research approaches for all study phases were evolved prior to initiation of field studies, but some minor changes in approach were made as the project proceeded, in an effort to optimize efficiency of data aquisition.

SITE VISITS

Prior to conducting in-depth evaluations, wastewater treatment facilities were subjected to a screening process, whereby plants experiencing problems of an operational or maintenance nature were identified. Throughout the project, this screening process has been referred to as the site visit phase. Generally, those plants which were reportedly experiencing operation and maintenance problems were recommended as candidates for comprehensive study in the preliminary evaluation phase.

The procedure for selecting treatment facilities to be examined in the site visit phase was established early in the project. As the eastern contractor, Gannett Fleming Corddry and Carpenter, Inc. (GFCC), contacted representatives at the EPA Region III office in Philadelphia, Pennsylvania, and requested assistance in obtaining information regarding candidate plants for site visits. Through a combined effort between the Region III office and the state regulatory agencies, plants were identified which appeared to comply with selection criteria developed to assist in differentiating between operational and nonoperational problems. Briefly, these selection criteria were:

1. The plant must incorporate some type of biological treatment process as the major wastewater treatment system. The processes considered include numerous activated sludge modes (conventional, extended aeration, complete mix, contact stabilization, step aeration, and pure oxygen), fixed film systems (trickling filter and rotating biological disc), and aerated lagoons.

2. Although not restrictive, a significant number of candidate plants should range in size from 3,785 to 18,925 m^3/d (1.0 to 5.0 mgd).

3. The plant should not be overloaded with respect to either flow or pollutant load, or have other readily identifiable design deficiencies.

4. The plant should not be in the process of designing or constructing additions to the facility for purposes of upgrading the degree of treatment.

5. The history of the facility should be such that the plant has encountered difficulty in achieving discharge limitations.

Utilizing data in their files, the Region III office compiled a preliminary list of candidate plants for site visits. Additions and comments were solicited from the Pennsylvania Department of Environmental Resources, the Maryland Department of Natural Resources, the Virginia State Water Control Board, and the West Virginia Department of Natural Resources. Following review by the state agencies, the lists of potential plants were reviewed by GFCC and plants were selected for site visits.

Following the selection of plants for site visits, the state agencies were requested to arrange the visits according to a schedule prepared by GFCC. In those cases in which the agencies preferred not to conduct the scheduling, GFCC personnel made arrangements directly with the facilities. Depending on the size of the facility, the type of treatment process, and the location of the plant, the duration of the visit was either one-half day or one day. Because of the informal nature of the visit, arrangements were typically made with the respective plant superintendents or chief operators.

Typically, the site visits consisted of a complete tour of each treatment facility and an interview of the superintendent or chief operator. Information gathered during the visits was divided into three major categories: general information, operation, and maintenance. The nature and extent of information collected under each of these categories is as follows:

General Information

Owner and operator of the treatment facilities, design flow, type of process, year of original construction, year of most recent upgrading, service population, raw wastewater characteristics (percentage of industrial waste), type of sanitary wastewater collection system (separate or combined with stormwater), name of receiving body of water, impact of infiltration/inflow, and impact of industrial wastewater discharges.

Operation

Number of operators, operational scheduling (eight hours per day, round-the-clock), staff certification (number of certified operators, levels of certification), operator training programs (i.e., Sacramento and Clemson series), analytical capabilities (apparatus, sampling techniques, testing methods, and records), process control testing, plant performance monitoring, process control techniques, technical references for operation (comprehensive operations manual, equipment manufacturer information), and use of consulting engineering services.

Maintenance

Staff capabilities for maintaining facility, age of equipment, spare parts inventory, preventive maintenance programs, emergency maintenance provisions, "housekeeping" practices, backup unit capabilities, technical reference for maintenance, and auxiliary power capability.

In addition to the foregoing, the plant superintendents were given the opportunity to verbally provide information regarding specific problems of both operational and design natures.

Following the visit, 2- to 3-page report was prepared which summarized the information collected during the site visit, noted the problems as stated by the superintendent, and recommended or rejected the facility for further study in the preliminary evaluation phase. Although site visits were conducted at 120 treatment facilities, formal reports, describing specific operational and maintenance programs, design criteria, and administrative practices were prepared for only 80 plants. In the early stages of the project, the purpose of the site visits was simply to screen facilities for further study. After completing about one-third of the visits, this phase of the project was expanded in scope to include preparing and submitting reports to EPA. Thus, the information reported for the plants varies with respect to the time of the site visit. As a means of quantifying the data collected during the site visits, each plant characteristic was assigned a numerical value from zero to three, having the following interpretations:

Rating	
3	Plant is deficient in this area. Capability is nonexistent. Considerable problems result.
2	Plant may be deficient in this area. Capability is inadequate. Some problems result.
1	Plant may be deficient in this area. Capability is marginally adequate. Little or no problems result.
0	No apparent deficiencies exist. Capability appears adequate. No problems are apparent.

Appendix A presents a tabulation of the data collected throughout the site visit phase of the project.

PRELIMINARY EVALUATIONS

The purpose of the preliminary evaluation phase was to examine the performance of the individual wastewater treatment facilities and the unit processes comprising each facility, to evaluate existing operation, maintenance, and administrative programs and practices, to identify and rank problems causing poor plant performance and to make specific recommendations for improving plant performance. In theory, the thirty plants chosen for preliminary evaluation were selected on the basis of experiencing operation and maintenance related problems, as identified during the site visit phase. However, a few plants were chosen as a result of employing relatively uncommon biological treatment processes (i.e., pure oxygen activated sludge) rather than because they were experiencing performance problems. This was done in an attempt to have the biological study based on as complete a data base as possible. In several cases, a problem which had been identified during the site visit as operational in nature was later determined, as a result of more in-depth information subsequent from the preliminary evaluation, to be design oriented. Consequently, not all the treatment facilities for which preliminary evaluations were conducted fully met all of the previously designated criteria for conducting such a study.

The original intent of the research approach was to exclude plants that were experiencing significant infiltration/inflow (I/I) problems. However, in the area designated for study under this contract, I/I was very widespread, due to high yearly precipitation, topography and geological conditions. Therefore, it was found to be impractical to exclude a site from further study for reasons of I/I alone, especially if the I/I problem was not causing severe hydraulic overloading. It was further felt that exclusion of plants with I/I present in their collection systems would bias the study results insofar as identification of problems at typical plants in the study area was concerned. For these reasons I/I alone was not considered a basis for rejection of a plant for continued study under the project scope. It might also be added that the presence of I/I was not always detectable during the short site visit due to the condition of flow monitoring devices, or the record keeping practices, at a given treatment plant.

As described above, plants were selected as candidates for preliminary evaluation from those to which site visits had been made. Because of the extensive scope of work required for the preliminary evaluation studies, three entities were normally contacted in order to obtain permission to conduct the survey; namely, the plant superintendent; municipal authority chairman, borough manager, or director of public works; and the consulting engineer for the facility. The scope and goals of the project were explained to each. Since assurance was given that the project was for research purposes, and that information obtained during the survey would not be used for purposes of enforcement, any misgivings were removed and permission to conduct the survey was granted in all cases.

The surveys were conducted at thirty biological wastewater treatment plants continuously from December 1975 to March 1977. Initially, five days were required to obtain the necessary data for preparing the preliminary evaluation report. However, as the field personnel became more familiar with the survey procedures, and more efficient data collection methods were developed, the individual investigations were reduced to 3-day studies. Similarly, in the early stages of the study, two or three field personnel, ranging from environmental technicians to registered professional engineers, were normally involved in the performance of each survey, whereas a single investigator normally conducted a survey later in the project. To some extent, however, the duration and manpower required for a preliminary evaluation study was a function of the size and complexity of the plant.

During a typical preliminary evaluation survey, the field personnel performed the following tasks:

1. Obtain plant monitoring records for year preceding site visit. Whenever possible, records included results of both process control and performance monitoring.

2. Conduct survey gaging, sampling, and analysis program, including field tests (i.e., pH, dissolved oxygen, settleable solids), major unit process influent and effluent monitoring, unit process sampling (i.e., mixed liquor), and sludge treatment process testing.

3. Complete Plant Evaluation Summary (Weighting and Ranking Table). This table provides the means for subjectively quantifying design, operation, maintenance, and administrative problems experienced at the treatment facility. Design factors, operation, maintenance, and administrative programs and practices are assigned a value from 0 to 3 which corresponds to decreasing degrees of quality and completeness.

4. Complete, or obtain previously completed, EPA Form 7500-5 (Report on Operation of Wastewater Treatment Plant). When completed previously by EPA personnel, this form contained usable information regarding operation and maintenance practices.

5. Examine present plant staffing noting distribution of labor efforts in the work categories of management, operation, maintenance, and laboratory.

6. Gather specific information on analytical capabilities including available laboratory equipment, sampling techniques, testing methods, test frequencies, and analytical records.

7. Observe process control techniques employed by operating staff.

8. Obtain basic design information for major unit treatment processes, including tank sizes, detention times, overflow rates, and loadings.

9. Obtain copies of National Pollutant Discharge Elimination System (NPDES) permit and state regulatory agency permit.

10. Secure copy of wastewater treatment budget or most recent record of expenditures.

11. Address specific questions to plant superintendent regarding maintenance practices to supplement information obtained during the site visit.

12. Review available operation and maintenance manual and similar references for content, including equipment information, maintenance schedules, laboratory and process control techniques, parts procurement, and as-built plans.

Upon completion of the field investigations, a preliminary evaluation report was prepared which set forth the findings of the survey, and evaluate the plant in terms of performance, design adequacy, operation and maintenance, and administrative procedures. The following items were included in the preparation of each report:

1. Use of a computer program, developed specifically for this project, for analyzing the plant performance data. The printout provided a mathematical interpretation of the plant influent and effluent quality, as well as individual unit treatment process loadings and operating parameters. Also, the plant effluent data were computed in terms of 7- and 30-day average concentrations for purposes of comparison with NPDES permit requirements.

2. Results of analyses at Gannett-McCreath Laboratories on wastewater and sludge samples collected during the survey. Tests typically conducted included BOD_5, various solids examinations, fecal coliform, nutrient analyses, and occasional metal determinations.

3. Comparison of plant design information with conventional design standards. Sources of such standards were the EPA process design manuals, the "Ten States Standards", and various wastewater treatment technology texts.

4. Comparison of plant performance data, using both the plant operating records and the results of the evaluation survey tests, with NPDES and state permit requirements.

5. Comparison of individual unit process performance parameters with accepted operating standards (i.e., primary clarifier efficiencies, overflow rates, detention times, MLSS concentrations, food-to-microorganism ratios, and mean cell residence times).

6. Use of a specially developed computer program for determining optimum staffing levels in accordance with the EPA report, "Estimating Staffing for Municipal Wastewater Treatment Facilities." The actual staffing patterns were then examined in light of the recommended levels.

7. Development of a unit cost for treatment using unit costs set forth in the EPA document "A Guide to the Selection of Cost Effective Wastewater Treatment Systems" and comparison with actual unit costs of treatment. Based on GFCC in-house experience and cost information, the unit costs from the document were adjusted to correct for increased labor and material costs. The adjusted values from the report were then used to compare expenditures at the various plants with average funding levels.

8. Conclusions and recommendations for improving performance. Recommendations were made for optimizing operation and maintenance practices, improving staffing and budgetary conditions, and making minor physical modifications.

SECTION 5

EVALUATION OF CAUSES OF LIMITED PLANT PERFORMANCE

In this section the various factors found in this study to affect treatment plant performance will be discussed in detail. The discussion will be broken down according to the four categories of data collected during the evaluations; administration, operation, maintenance, and design.

ADMINISTRATION

Traditionally, wastewater treatment has been a low priority item for many municipalities. Even in those cases where authorities have been formed to meet the needs of the community, the attitude that properly treating the sanitary wastewaters is not as important as other municipal functions frequently prevails. In many cases local governments and authorities are reluctant to increase taxes or sewer use rentals to offset rising costs of treatment because of the general attitude of the public toward waste treatment. It is somewhat paradoxical that although public opinion has moved toward improving the environment in recent years, the need for improved performance of existing treatment facilities is not often considered in the same context by the public. As a result many treatment facilities are operated with inadequate budgets or staffs. As an average, salaries of wastewater treatment plant personnel are below the level for persons with similar technical responsibilities. Therefore, the personnel employed generally require considerable on-the-job training to compensate for a minimal technical background.

During the preliminary evaluation phase, plant administration was examined with respect to expenditures, staffing, operator motivation, administrative policies, and morale. In particular, budgetary and staffing matters were examined in detail. Areas such as operator salary scales, motivation, and morale were rarely found to be primary sources of performance problems in the thirty plants studied. Specifically, insufficient salary was identified as a source of significant problems at only two treatment plants. Motivation was identified as a minor problem at four installations. Our own previous experience has indicated that treatment facilities can be operated to produce an acceptable effluent (e.g., meets permit requirements) despite low salary levels. However, we must be extremely careful when interpreting the findings of this study relative to salaries, motivation and related areas. During an evaluation of the type comprising this study, where the investigators are exposed to the plant staff for only a short time, problems of low morale and salary dissatisfaction can go undetected. Furthermore, the results of low salary scales may be indirect. For example, high-priority primary performance-limiting problems such as lack of implementation of process control techniques or inadequate testing may be caused, in part, by the lack of incentive assocaited with low salary scales and unidentifiable opportunities for advancement. Upgrading the salary level of the wastewater treatment plant operator classification position should put the municipality in a position to compete for more technically qualified individuals. This would, in turn, increase professionalism in the treatment industry and result in more conscientious operation of facilities.

Adequate funds are required to effectively operate and maintain treatment facilities. The rising costs of labor, energy, chemicals, and equipment parts should be met by the users of the treatment systems. During the preliminary evaluation phase, the current budgets or actual expenditures, where available, were examined. From this information, the unit cost of providing wastewater treatment was determined for each facility using its design flow as a base. The results are presented in Figure 1. The dispersion of the data points result from process variables such as the need for chemical addition, use of additional unit treatment processes (primary clarification, filtration, and effluent polishing), and methods of sludge treatment and disposal. Variations in quality and completeness of budgets submitted also contributed to dispersion in the data. As indicated, unit costs of treatment ranged from 50 cents per 3.78 m^3/d (1,000 gallons) for a small, package-type plant to less than 15 cents per 3.78 m^3/d (1,000 gallons) for a large, activated sludge facility. Although the data points are widely scattered, an economy of scale is indicated by the regression line.

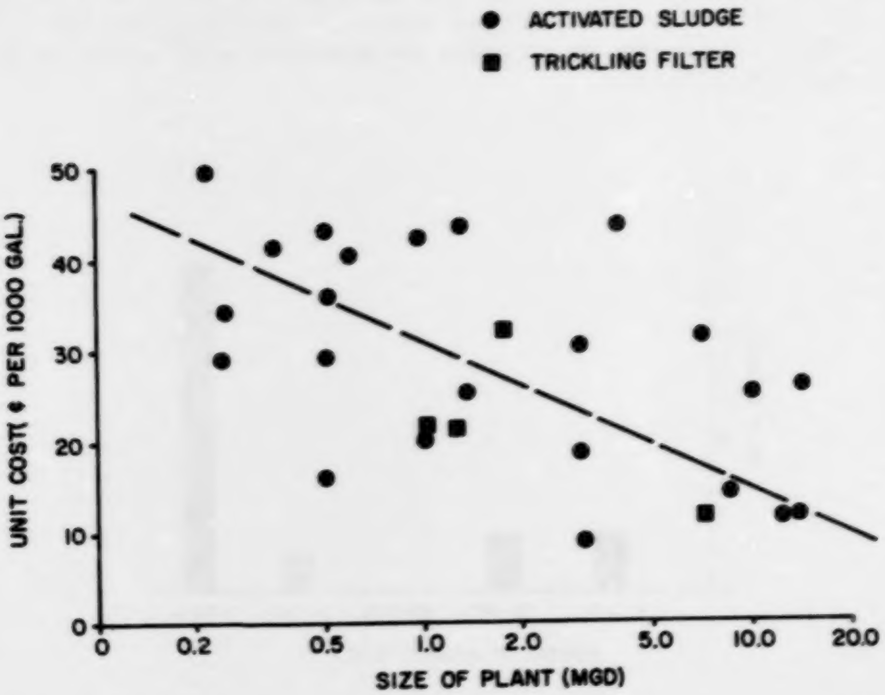


Figure 1. Relationship Between Operation and Maintenance Expenditures and Design Plant Flow

To roughly assess the adequacy of the funds allocated for wastewater treatment at each of the plants studied, a common reference was needed to serve as a basis for comparison. The EPA technical report entitled, "A Guide to the Selection of Cost-Effective Wastewater Treatment Systems," was used as a means for computing theoretical operation and maintenance cost requirements for various sizes and types of treatment facilities. Inasmuch as the EPA document was developed to perform relative cost comparisons among process trains and not for absolute cost estimation, adjustments to the factors set forth in the publication were made based on GFCC experience. Adjustments to the cost data were made to account for inflation and increased cost of power and materials since those data were collected and published. Theoretical unit costs were calculated for each preliminary evaluation plant and compared to the unit operational costs, determined using the plant budget and records of expenditures.

The comparison of the treatment costs incurred at 30 plants with the derived costs (from EPA reports) of operation based on type and size of facility is shown in Figure 2. Actual expenditures at 18 of the plants surveyed were equal to or exceeded by the respective derived costs and were within 10 percent of the derived costs at two additional plants. However, six plants indicated expenditures at least 20 percent less than the derived amount for operation and maintenance. As might be expected, those six plants found to be significantly underbudgeted also were found to have other operation and maintenance shortcomings. Size and coverage of the plant staff and familiarity of the local administrative body with the needs of the plant were rated statistically poorer at the underfunded plants. Knowledge of wastewater treatment theory and preventive maintenance practices also tended to be rated lowest at those facilities.

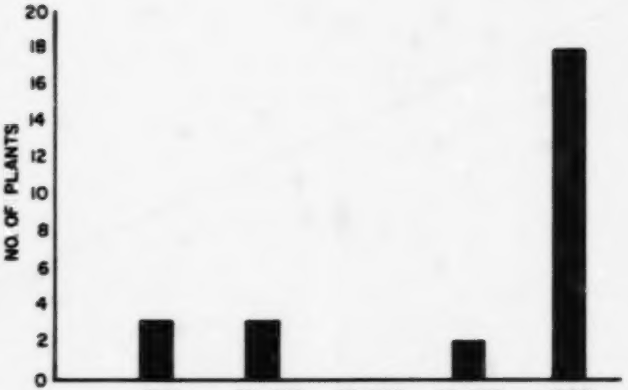


Figure 2. Comparison of Actual Operation and Maintenance Costs with Average Costs at Similar Plants

Proper staffing, with respect to both numbers and capabilities, is the key to effective operation of any wastewater treatment plant. During both the site visit and preliminary evaluation phases, considerable effort was devoted to examining staff capabilities at each plant. Figure 3 shows the relationship between plant capacity and staff size for the plants examined during the site visit phase. The figure shows the number of staff per unit of treated flow decreases as design capacity increases above 37,850 m^3/d (10 mgd).

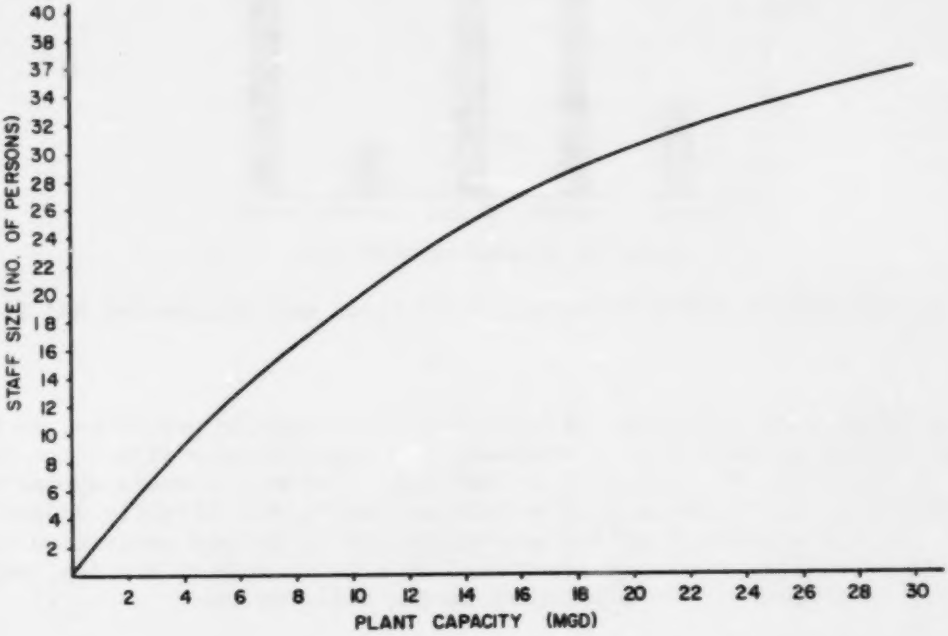


Figure 3. Relationship Between Plant Capacity and Staff Size

As with budgeting, a published document was used as a basis for comparison to evaluate staffing adequacy. The EPA document, "Estimating Staffing for Municipal Wastewater Treatment Facilities," was used to determine a recommended staffing requirement for each of the preliminary evaluation plants. Using the procedures in this report, the levels of effort to be devoted to the six major labor categories (supervisory, operation, maintenance, laboratory, yardwork, and clerical) were determined for each plant. These requirements were then compared with the actual labor distribution as given by the superintendent at each facility. Figure 4 shows the comparison between actual and recommended staff levels. As the figure indicates, nine of the 30 plants were staffed at a level at least 20 percent less than the recommended number. This analysis is necessarily quite crude and serves only as a "first cut" look at the plant

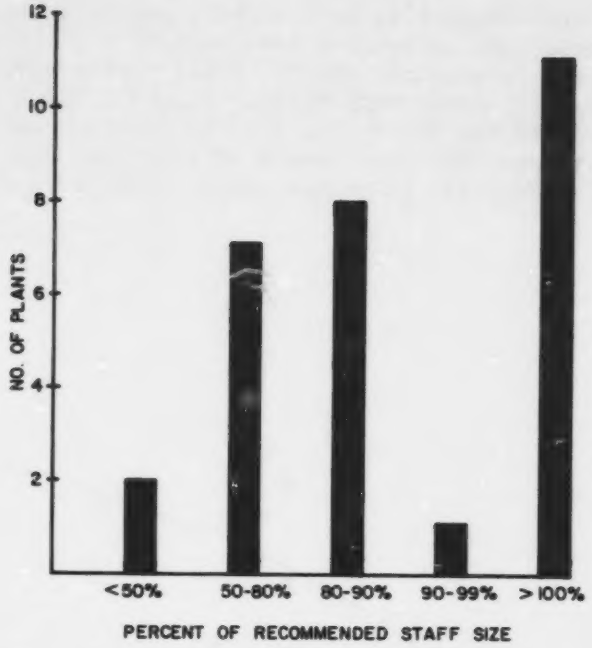


Figure 4. Relationship Between Actual Staff Sizes and Recommended EPA Staff Levels

staffing picture. Assumptions intrinsic to the estimating procedure, such as the quantitative productivity of manpower, can significantly affect the results. On the basis of reasonable assumptions, however, it would appear that about one-third of the preliminary evaluation plants were slightly understaffed. As was earlier discussed concerning the salary and motivation situation, understaffing, while not identified as a major primary problem, may indirectly contribute to the plant performance deficiencies.

Table 2 presents a summary comparison of actual and recommended distributions of labor for the preliminary evaluation plants. Upon inspecting the table, several points were noted:

1. With respect to supervision and operation, no discernable pattern existed. The number of plants with inadequacies (28) was approximately equal to the number with excessive efforts (25) devoted to the two categories.

2. Overall, manpower allocated to laboratory functions exceeded the recommended level. This is not consistent with the low degree of process control testing observed at the study sites. No relationship appeared to exist between the complexity of the plant monitoring requirements and the laboratory manpower.

TABLE 2. ACTUAL AND RECOMMENDED LABOR EFFORT DISTRIBUTIONS

Plant No.	Supervision			Operation			Laboratory			Maintenance			Yardwork			Office/Clerical		
	Number		Difference (%)	Number		Difference (%)	Number		Difference (%)	Number		Difference (%)	Number		Difference (%)	Number		Difference (%)
	Actual	Recommended		Actual	Recommended		Actual	Recommended		Actual	Recommended		Actual	Recommended		Actual	Recommended	
101																		
102	0.5	0.1	+ 400	1.0	0.6	+ 67	0.0	0.1		1.0	0.4	+ 150	0.0	0.2	-	1.0	0.0	
103	0.125	0.2	- 38	0.5	0.7	- 29	0.0	0.2		0.5	0.5		-	-	-	-	-	-
104	0.5	0.2	+ 150	0.25	0.5	- 50	0.62	0.3	+ 107	0.5	0.6	- 17	0.0	0.1	-	-	-	-
105	0.0	0.2		0.125	0.8	- 84	0.25	0.2	+ 25	0.6	0.5	+ 20	0.0	0.2	-	-	-	-
106	1.0	0.8	+ 25	6.0	5.2	+ 15	1.0	1.0		2.0	3.0	- 33	4.0	1.2	+ 233	1.0	0.2	+ 400
107	1.0	1.6	- 38	11.0	9.4	+ 17	2.0	1.8	+ 11	2.0	4.7	- 57	4.0	1.6	+ 150	2.0	0.7	+ 185
108	1.0	0.4	+ 150	3.0	2.2	+ 36	1.0	0.0		2.0	2.0		2.0	0.5	+ 300	1.0	0.1	+ 900
109	1.0	1.2	- 17	4.0	6.5	- 39	2.0	1.0	+ 100	1.0	3.3	- 70	6.0	1.1	+ 446	-	-	-
110	2.0	1.1	+ 82	4.0	4.6	- 13	1.5	1.5		3.0	3.2	- 6	1.0	2.1	- 52	-	0.6	
111	0.5	0.3	+ 67	1.5	1.7	- 12	0.3	0.4	- 25	0.9	1.2	- 25		0.3		-	-	-
112	0.1	0.2	- 50	1.25	1.0	+ 25	0.5	0.3	+ 67	0.1	1.0	- 900	0.1			0.1	0.0	
113	1.0	0.6	+ 67	11.0	3.5	- 71	2.0	2.0			1.2		1.0	0.3	+ 233		0.1	
114	0.1	0.2	- 50	0.9	0.8	+ 13	0.5	0.3	+ 67	0.4	0.8	- 50	0.1	0.2	- 50	-	-	-
115		0.2		1.0	1.0		0.5	0.3	+ 67	0.25	0.7	- 64	0.25	0.1	+ 150	-	-	-
116	1.0	0.6	+ 67	5.0	4.4	+ 14	1.0	0.7	+ 43	2.0	3.4	- 41	1.0	0.6	+ 67		0.1	
117	0.13	0.18	- 28	0.25	0.40	- 38	0.15	0.01	+1400	0.25	0.50	- 50	0.22	0.1	+ 120		0.01	
118		0.2		0.16	1.8	- 91	0.19			0.48	1.0	- 52	0.17	0.3	- 43	-	-	-
119	0.5	0.4	+ 25	1.25	1.1	+ 14	0.75	0.2	+ 275	0.7	0.8	- 13	0.25	0.2	+ 25	0.05		
120	0.5	0.4	+ 25	1.75	1.3	+ 35	0.63	0.3	+ 110	1.75	1.1	+ 59		0.4		0.25	0.1	+ 150
121	0.5	0.2	+ 150	1.0	0.6	+ 67	1.0	0.4	+ 150	0.5	0.6	- 17		0.3		-	-	-
122	1.0	1.3	- 23	8.0	7.6	+ 5	1.0	1.5	- 33	1.0	3.5	- 71		1.9			0.5	
123	0.0	0.2		0.13	0.4	- 68	0.23	0.3	- 23	0.25	0.7	- 64		0.1		-	-	-
124	1.5	2.4	- 38	12.0	13.2	- 9	3.0	1.8	+ 67	2.0	4.4	- 55	2.0	0.9	+ 122	0.5	0.9	- 44
125	1.75	1.1	+ 59	6.0	8.1	- 26	0.5	1.4	- 64	1.0	3.9	- 74	1.0	1.1	- 9	0.5	0.4	+ 25
126	.25	0.6	- 58	4.5	4.6	- 2	0.5	0.5		3.0	2.8	+ 7		0.6			0.1	
127	0.25	0.3	- 17	0.88	1.6	- 45	0.25	0.2	+ 25	0.63	1.2	+ 48	0.5	0.3	+ 67			
128	2.0	2.3	- 13	12.0	16.2	- 26	3.0	2.1	+ 43	5.0	4.0	+ 25	4.0	1.9	+ 110	1.0	0.9	+ 11
129	0.5	0.3	+ 67	1.6	1.9	- 16	0.6	0.4	+ 50	0.2	1.5	- 87	0.1	0.3	- 67	-	-	-
130	0.25	0.3	+ 17	0.5	2.2	- 77	1.0	0.5	+ 100	1.5	1.7	- 12	0.75	0.3	+ 150	-	-	-

3. Sufficient manpower was not devoted to maintenance. Of the major labor categories, deficiencies in manpower were the greatest for maintenance.

Adequate staff size alone is not sufficient. The personnel at the wastewater treatment facility should be trained and appropriately certified, and should have an understanding of basic treatment fundamentals. For this study the use of training programs by treatment plant personnel was defined as the operator's enrollment in relevant courses. The adequacy or inadequacy of such courses has not been determined in this study. Similarly, certification refers to the level and number of certified operators at a particular facility, irrespective of the requirements of the certification programs or their effectiveness.

Information obtained from the treatment plant personnel during the site visit phase has been interpreted to evaluate the basic capabilities of the operating staff. The term "staff capabilities", is a composite of the numerical values (see Section 4 - Research Approach) assigned to the staff-related characteristics. To develop the composite characteristic, four primary factors (staff size, training, certification, and treatment understanding) have been weighted, according to their estimated impact on the overall capability of the staff, and combined. According to the weighting system, both staff size and treatment understanding have been weighted heavier than training and certification, since in our experience the former two characteristics more directly impact the performance of the plants. For purposes of graphical presentation, the levels of quality of completeness corresponding to the numerical ratings (0, 1, 2, or 3) have been shown as good, fair, poor, and critical. Figure 5 shows the relative number of plants having good, fair, poor, or critical staff capabilities. As the figure indicates, staff capabilities at 69 percent (or 73 of 106 plants so rated) were judged adequate. The reader is reminded that this analysis includes all plants visited under the site visit phase. Therefore, in many cases judgements concerning staff capabilities were the result of observations over a period of less than one day.

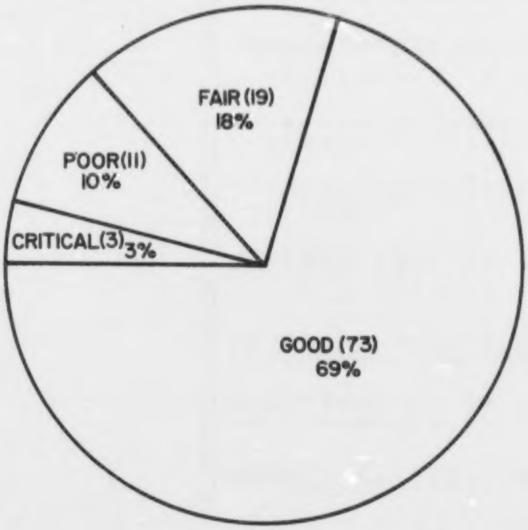


Figure 5. Overall Staff Capabilities at Site Visit Plants

DESIGN

Each preliminary evaluation included the examination of plant design information. Included were the analyses of total plant hydraulic and organic loadings, unit process designs, including sludge treatment processes, and plant flexibility. Since the primary objective of the project was to identify areas in which increased performance efficiency could result through improved operation and maintenance practices, design-limiting factors had to be identified before the potential of improved operation and maintenance programs could be evaluated.

As noted previously, the main purpose of conducting the site visits was to screen out plants not suitable for the more extensive preliminary evaluation. One of the criteria for selection as a preliminary evaluation plant was that the facility should not be hydraulically or organically overloaded to a significant extent. For this reason, only a few plants studied in that phase were subjected to hydraulic and pollutant overloads as a result of nonextraneous noninfiltration/inflow related discharges. For the most part, the organic overloads were a result of industrial wastewaters containing high pollutant concentrations. Of the 30 plants evaluated, five were reportedly experiencing organic overloading. The nature of the overloads was such that fluctuations in influent BOD_5 levels, rather than a continuous overload, were reported at the treatment plants, presumably the result of slug industrial discharges.

Continuous hydraulic overloading did not occur at any preliminary evaluation plants. The majority of the plants were experiencing excessive fluctuations in hydraulic loadings, occasionally exceeding design capacities. This situation was attributed to infiltration of groundwater and storm-water inflow, rather than legitimate discharges from sewered customers. Infiltration/inflow is a widespread, almost universal, problem in treatment plant collection systems in the geographical area of this study, although the problem varies in degree. In several instances the volume of infiltration/inflow was sufficient to cause major treatment process upsets in suspended growth systems, either by causing a "washout" of solids from the secondary clarifier or by diluting the sanitary wastewater to the point that a reasonable biomass loading could not be maintained.

Figures 6 and 7, respectively, show a distribution of plants with respect to present average flow as a function of design capacity for the site visit and preliminary evaluation phases. As Figure 6 indicates, recorded flows at 27 plants examined under the site visit phase exceeded the design hydraulic capacity on an average daily basis. This was a surprisingly high number considering that the site visit plants were selected from lists supplied by state environmental control agencies who were instructed to exclude hydraulically overloaded plants from consideration. It appears there is some need for state regulatory agencies to update their information relative to treatment plant status. Figure 7 shows that investigations during the preliminary evaluation phase showed two plants to be 25 to 50 percent hydraulically overloaded on an average daily basis. Five plants were found to be hydraulically overloaded, but at a level of less than 25 percent over design. As previously discussed the two plants experiencing the higher overloads had major performance problems

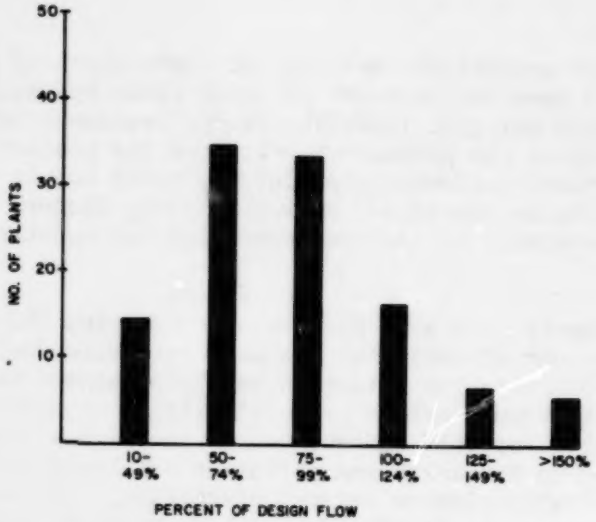


Figure 6. Present Average Flow as a Function of Design Flow (Site Visit Phase)

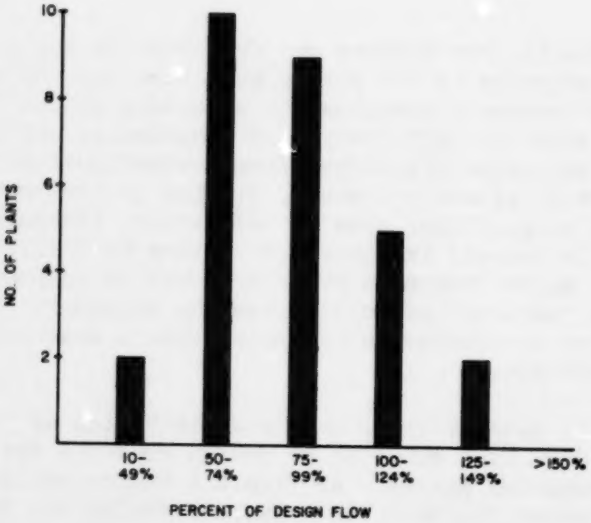


Figure 7. Present Average Flow as a Function of Design Flow (Preliminary Evaluation Phase)

attributable to hydraulics. It was doubtful that operation and maintenance techniques could overcome this design problem at those two facilities.

A comparison of unit process design to actual operating conditions was made on an individual unit basis at each preliminary evaluation site. Design information was obtained from the plant basis of design and drawings where available. These were supplemented by field measurements where necessary. Design adequacy was judged on the basis of experience and recognized published information including: various EPA process design manuals; the "Recommended Standards for Sewage Works - Great Lakes-Upper Mississippi River Board of Sanitary Engineers", commonly referred to as the Ten-States Standards; and wastewater treatment technology texts. Since the design of nearly all existing secondary wastewater treatment plants was subject to the review of the respective state environmental agencies, the unit process design of these facilities would be expected to conform with the design criteria adopted by the individual states, such as the Ten-States Standards. Nevertheless, unit processes at several plants were noted to be improperly designed. At several plants, sufficient detention time was not provided as a result of inadequate baffling in the chlorine contact tank, possibly resulting in incomplete disinfection. At Plant 059, weir loadings in the primary clarification stage exceeded the recommended limit by 500 percent, causing solids carry-over to subsequent unit processes. At one contact-stabilization facility, Plant 006, the two discrete aeration stages were not separated as called for in the design, although performance problems could not be directly identified as a result of this deficiency.

A basic problem was noted in the design of the contact-stabilization process at several plants. Specifically, excessive detention time was provided in the contact aeration stage. These plants were designed in accordance with appropriate state standards, but it is the design standards which erroneously specified the extended contact detention time to provide a factor of safety. In practice, the excessive contact times have been shown to result in premature stabilization in the contact zone and, subsequently, a near-endogenous condition in the reaeration zone. As a result, the adsorptive properties of the active biomass in the contact zone were not fully utilized and the biological process did not perform as intended. In effect, the factor of safety subverted the biological theory on which the contact-stabilization process is based.

As opposed to process design errors, a number of plants were found to have other design deficiencies, such as the lack of grit removal or primary clarification units, resulting in excessive primary solids being conveyed to the biological units. Although the majority of the facilities designed without such preliminary and primary units did not appear to be adversely affected on a regular basis, according to the plant staffs, performance problems at those plants periodically occurred as a result of the inability to keep inert solids from entering the biological phase.

Process controllability was found to be a problem primarily with the smaller package-type (contact-stabilization or extended aeration) treatment facilities. Suspended growth systems sized less than 3,785 m3/d (1 mgd) often lacked the capability to vary and monitor air supply and to control return sludge rates. Similarly, many of the package-type facilities were outfitted with air-lift pumps for returning activated sludge which have historically limited the ability of the operators to control the process. Controllability at many plants was limited by sludge handling and disposal facilities. This will be discussed further below.

Built-in operating flexibility was reported to be a constraint in two cases. Although a number of plants (predominantly the smaller facilities) did not have multiple unit capabilities for the major unit processes, performance problems were rarely associated with that deficiency. The majority of the package-type activated sludge treatment plants could be operated in only a single mode (e.g., complete mix, extended aeration, contact-stabilization). However, in no cases did a preliminary evaluation conclude that performance problems would be reduced or eliminated through changing modes of operation. In addition, the inability to bypass individual treatment units frequently resulted in difficulty in performing maintenance service on those units, although performance was usually not adversely affected on a long-term basis.

Several plants studied during the preliminary evaluation phase were experiencing performance problems as a result of design deficiencies (or errors) relative to sludge treatment and disposal. At a number of activated sludge facilities, inadequate sludge stabilization and dewatering capabilities resulted in excessive solids being retained in the treatment system or discharged in the final effluent. At Plant 005, the drying beds were critically undersized, which prevented the operator from wasting sludge at proper intervals. A problem at Plant 093 was reported to be a combination of inadequate sludge digestion and drying capacity, and insufficient sludge disposal sites. As a result of inadequate sludge thickening capacity at Plant 059, the wet oxidation unit could not sustain itself at the sludge wasting level required by process considerations without auxiliary fuel. Therefore, to save fuel costs, sludge wasting was controlled by the capacity of the thickener to produce a suitably thickened sludge.

It should be noted that control of sludge wasting rate is the primary mechanism for control of the activated sludge process, regardless of specific control strategy used (e.g., F/M, SRT, or oxygen uptake control). But a major finding of this study is that process control is not being applied by most operators. Therefore, many may not even be aware of sludge handling inadequacies until they become severe enough to result in physical problems.

Performance problems at two facilities appeared to be related solely to the poor performance of proprietary biological units in the process scheme, rather than to system design errors. At Plant 048, a relatively uncommon proprietary activated sludge unit called an Aero Accelator was cited as the source of performance problems. The physical characteristics of the unit were such that intermixing of the thickening zone in the clarification chamber and the aeration zone existed, causing turbulence, thereby inhibiting settling and limiting return sludge solids concentrations. In the second situation, Plant 077, which uses a combination of trickling filters and rotating biological contactors, was not obtaining the level of treatment from the bio-discs that was guaranteed by the manufacturer. Attempts to improve performance through varying the mode of operation had met with little success.

In summary, the primary purpose of the preliminary evaluation phase was to identify operation and maintenance related problems limiting plant performance and making recommendations for their alleviation. However, routine examination of design parameters showed many plants, previously thought to be adequately designed, had design-related problems. Such design problems, if not corrected, would limit the degree to which improved operation and maintenance programs could upgrade plant performance. Recommendations for corrective operation and maintenance programs must be made within the constraints of design adequacy.

OPERATION

The third major category of factors affecting plant performance is that of operation, which includes process control adequacy and capabilities, use and adequacy of the plant laboratory, and technical guidance availability. Assessing various aspects of plant operation was necessarily a subjective procedure based on the experience of the preliminary evaluation field personnel, all of whom were engineers and licensed operators. Factors were rated as adequate, marginal, inadequate, or nonexistent. Evaluation of specific practices or capabilities took into account related factors such as plant size, process type, and permit requirements. In this sense the standards against which operational factors were judged varied among plants. However, the meanings of the four descriptive terms in all cases were the following:

1. Adequate - practice or capability was not limiting to plant performance, and could not be substantially improved.
2. Marginal - practice or capability was not normally limiting to plant performance, but could be improved.
3. Inadequate - practice or capability was insufficient to the extent that it inhibited plant performance.
4. Nonexistent - no provision existed at the plant for that facet of operation.

Information concerning the laboratories at the preliminary evaluation plants is graphically summarized in Figure 8. The laboratories of the plants surveyed generally met the requirements for performance monitoring established under federal and state agency permits. Three-fourths of the plants displayed adequate or marginally adequate laboratory equipment and analytical capabilities. Most plants followed approved procedures for sample collection, preservation, and analysis, and kept records documenting the results. Several of the smaller plants used an outside laboratory for monitoring.

Most plants possessed the equipment and capabilities to perform process control testing. However, testing programs for this purpose were less satisfactory than they were for performance monitoring. Many smaller facilities did not monitor such important parameters as the mixed liquor suspended solids and settleability in suspended growth systems. A surprising number of facilities of all sizes had never determined any basic process control parameters such as the F/M, MCRT, or SVI.

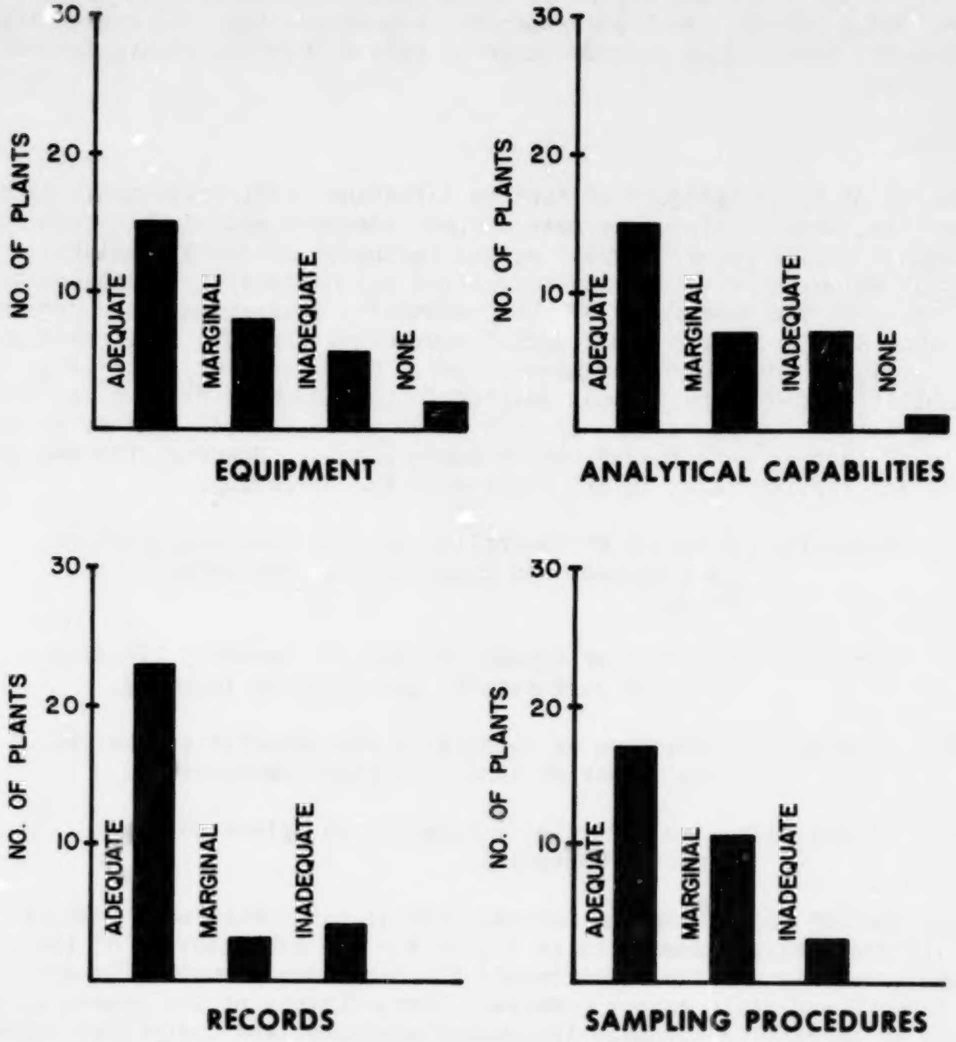


Figure 8. Operation and Maintenance Performance Indicators - Plant Laboratory

In the area of process contrcl procedures shown in Figure 9, staffs at 17 of the plants showed an adequate understanding of process control fundamentals, based on personal interviews and assessment of training levels. However, fewer than half of the staffs applied such knowledge to plant operation in an attempt to exercise control and stabilize the process.

Preliminary reasons appeared to be the inabilities to interpret laboratory data, determine and implement operating changes, and evaluate the system response. This was particularly true for suspended growth systems where process control is most complex.

In varying degrees of completeness, the plant staffs had several resources available for technical operating assistance, including consultant-prepared O&M manuals, manufacturers' equipment information, and operations assistance from consulting engineers or other experts. Figure 10 presents a graphical summary of various criteria used to evaluate plant operating manuals, including completeness, clarity with which operating procedures are set forth, information on key equipment (i.e., pumps and aerators), and level of use by plant personnel. As the figure indicates, half of the plants surveyed lacked a complete O&M manual. Even in plants where an O&M manual was available, the manual frequently contained no detailed operating procedures or ranges for key process control parameters. The O&M manuals examined relied heavily on the equipment and maintenance information supplied by the manufacturers, but lacked process control instructions. In some cases a binder of equipment information was all that was available. Also, the figure shows that operators frequently did not make use of the manuals and were often unfamiliar with ther content.

Manufacturers' equipment information is typically provided to plants. Such literature usually contains satisfactory instructions for required maintenance and procurement of spare parts. It was found that plants having this material used it often. However, such information was of no use as far as operating procedures or process control parameters were concerned, and is not considered a substitute for a comprehensive O&M manual.

Another source of technical operating assistance is the consulting engineer. Most of the treatment plants studied reported having occasional contact with the design engineer, but had no formal arrangement with a consultant for technical assistance. Operational and process expertise available through consulting engineers and other experts remains a little-used resource at this time.

MAINTENANCE

Treatment plant maintenance was evaluated in terms of preventive and emergency capabilities, treatment reliability, and causes of inadequate maintenance.

Routine maintenance indicators, including intervals between preventive maintenance on equipment, spare parts supplies stocked at the plant (bearings, seals, etc.), treatment reliability or absence of downtime, and housekeeping practices (laboratory orderliness, yard appearance, etc.) were evaluated

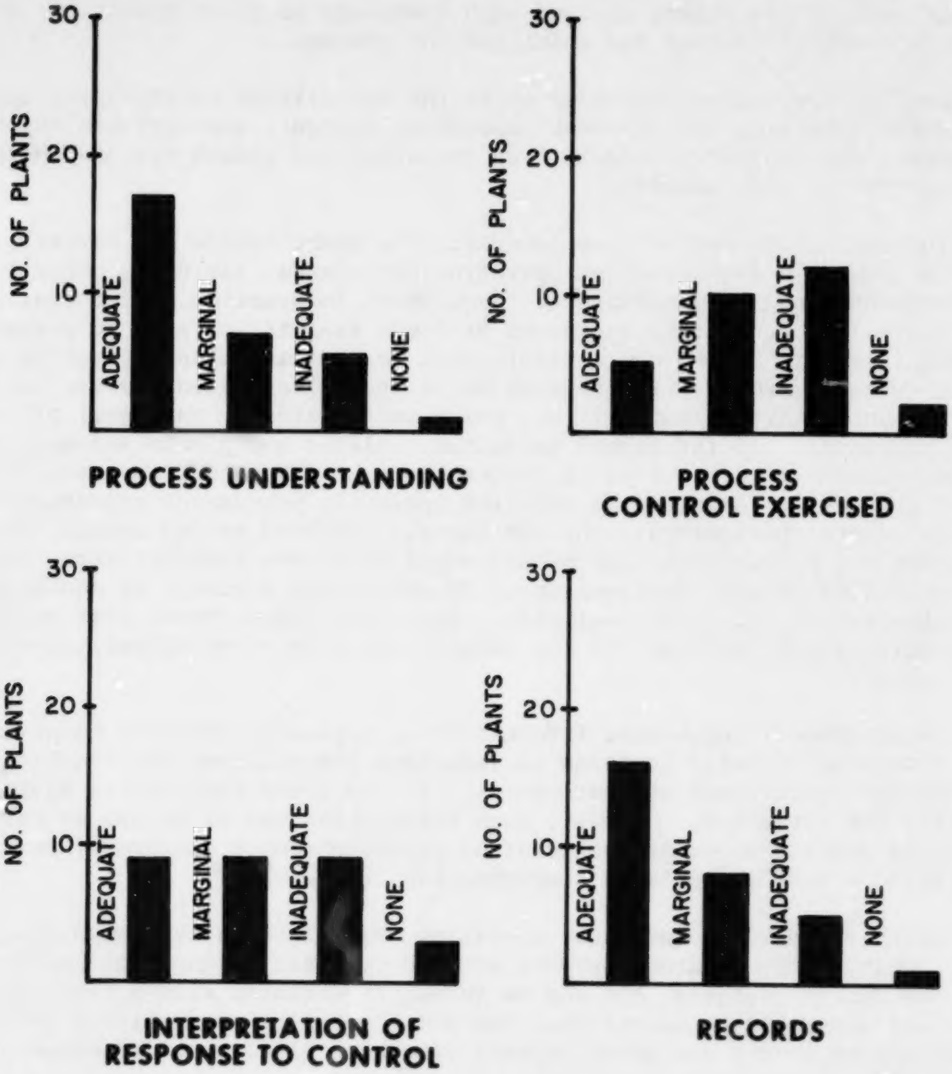


Figure 9. Operation and Maintenance Performance Indicators - Process Control Procedures

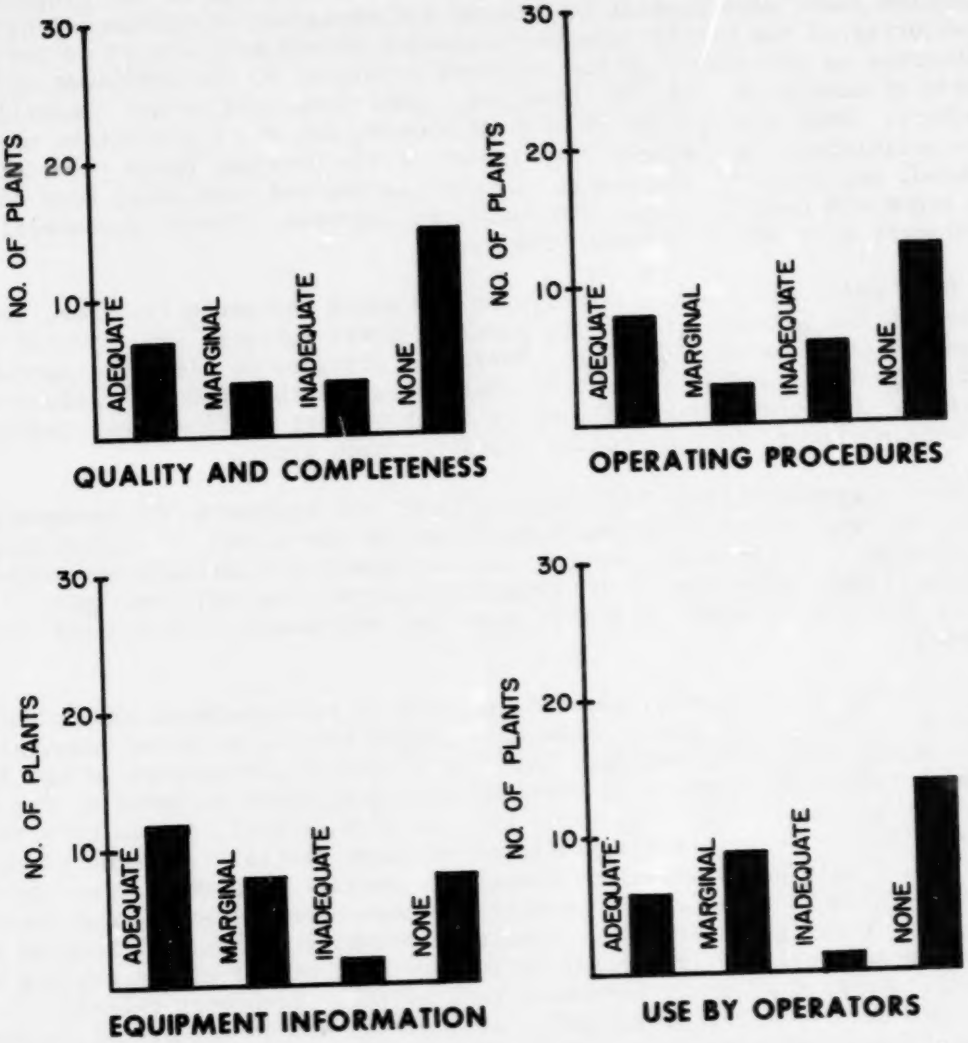


Figure 10. Operation and Maintenance Performance Indicators - Operation and Maintenance Manual

individually. Also, emergency maintenance capabilities, such as backup units, ease of procuring parts, records of repairs, and the presence of alarm systems were evaluated. Figures 11 and 12 summarize the findings of the prelimianry evaluation phase with respect to routine and emergency maintenance programs. The majority of the plants surveyed performed an adequate amount of preventive maintenance as determined by the observed condition of the equipment and records of maintenance-related downtime. Housekeeping also was generally satisfactory. Most plants kept records of repairs and major preventive maintenance activities, including a description of the problem, parts repaired or replaced, and the date of repair. Record keeping and scheduling were often less organized than desirable, and could be improved. Parts accessibility and procurement were not a frequent problem.

Both audio and visual alarm systems to major equipment failures, such as failure of the influent wastewater pumps or power outages, were present in 67 percent of the treatment systems. These are designed to alert the operator (or alert other individuals if plant is unattended) in the event of failure or abnormality. Failure of other motorized or electrical equipment was indicated with warning lights on the control panels at each plant.

Nearly all facilities had portable pumps and equipment for emergency recovery, although there exists much variation in the amount of suitability of such equipment. Additional manpower and equipment was normally available from other municipal departments. Most plants, however, had not developed a problem-specific response plan that could be implemented in the event of an emergency.

As Figure 12 indicates, about 85 percent of the treatment plants surveyed in the preliminary evaluation phase were judged to have at least marginal or better backup unit availability. This was a natural consequence of the fact that most treatment plants were designed with dual units in parallel for the key unit processes. Only very small [<3,785 m^3/d (1 mgd)] plants were the exception. Dual or multiple units allowed at least partial treatment to continue when a unit was down for maintenance. Partial treatment refers to the fact that the unit remaining in service may have been overloaded and unable to operate at design efficiency. Regular preventive maintenance coupled with the backup unit availability resulted in over half of the plants studied being judged to have adequate treatment reliability. Treatment reliability in this sense refers to the minimization of downtime due to mechanical failures, not to effluent quality. Those plants that did demonstrate inadequate treatment reliability were characterized by excessive delays in response to equipment malfunctions. This was often due to difficulties in procuring replacement parts.

In addition to the above discussed ratings assigned to various maintenance factors, several additional observations should be noted. Maintenance staffing was generally below levels recommended in EPA reports. This was most noticeable in small plants. The degree of adverse impact on plant performance due to maintenance inadequacies was greater for suspended growth systems than for trickling filter plants. This was a result of the greater complexity and interdependency of unit processes at the former facilities. Finally, while 75 percent of the plants carried at least a marginal supply of

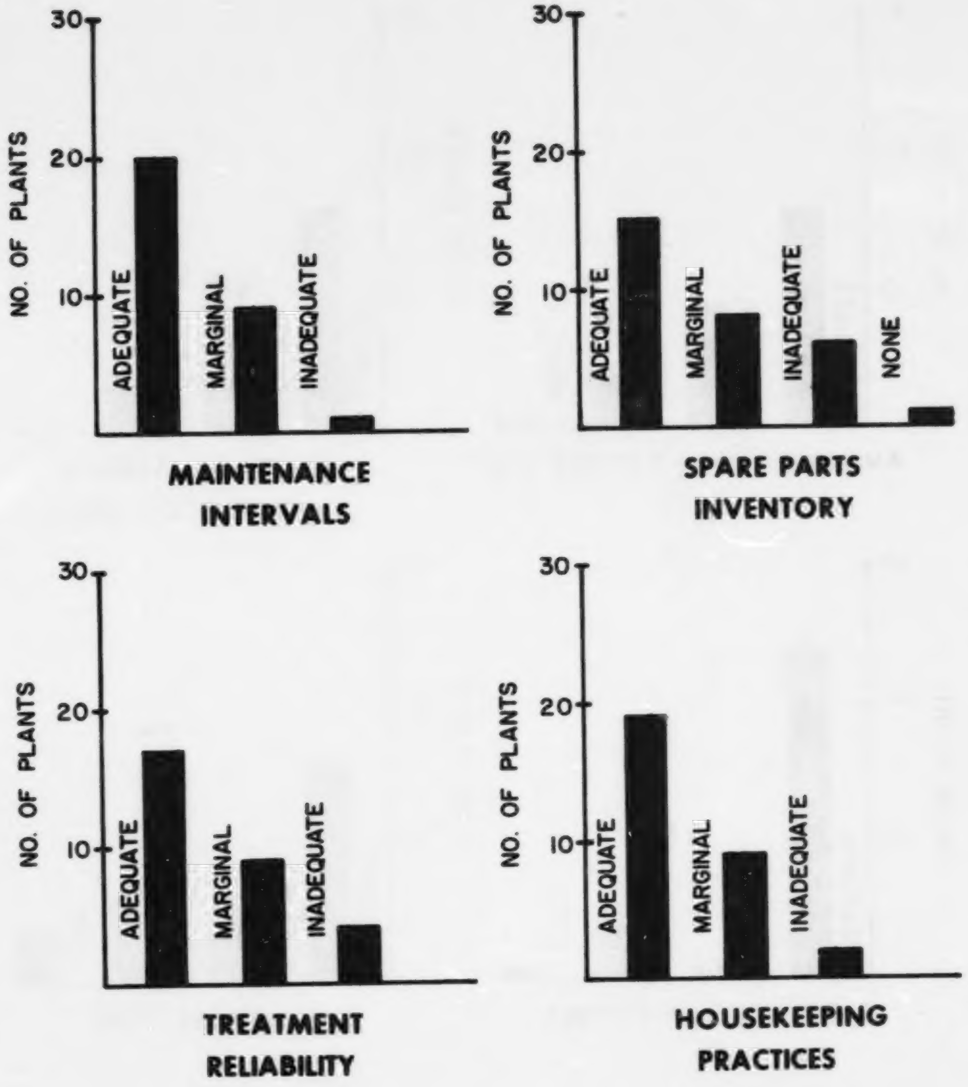


Figure 11. Operation and Maintenance Performance Indicators - Routine Maintenance

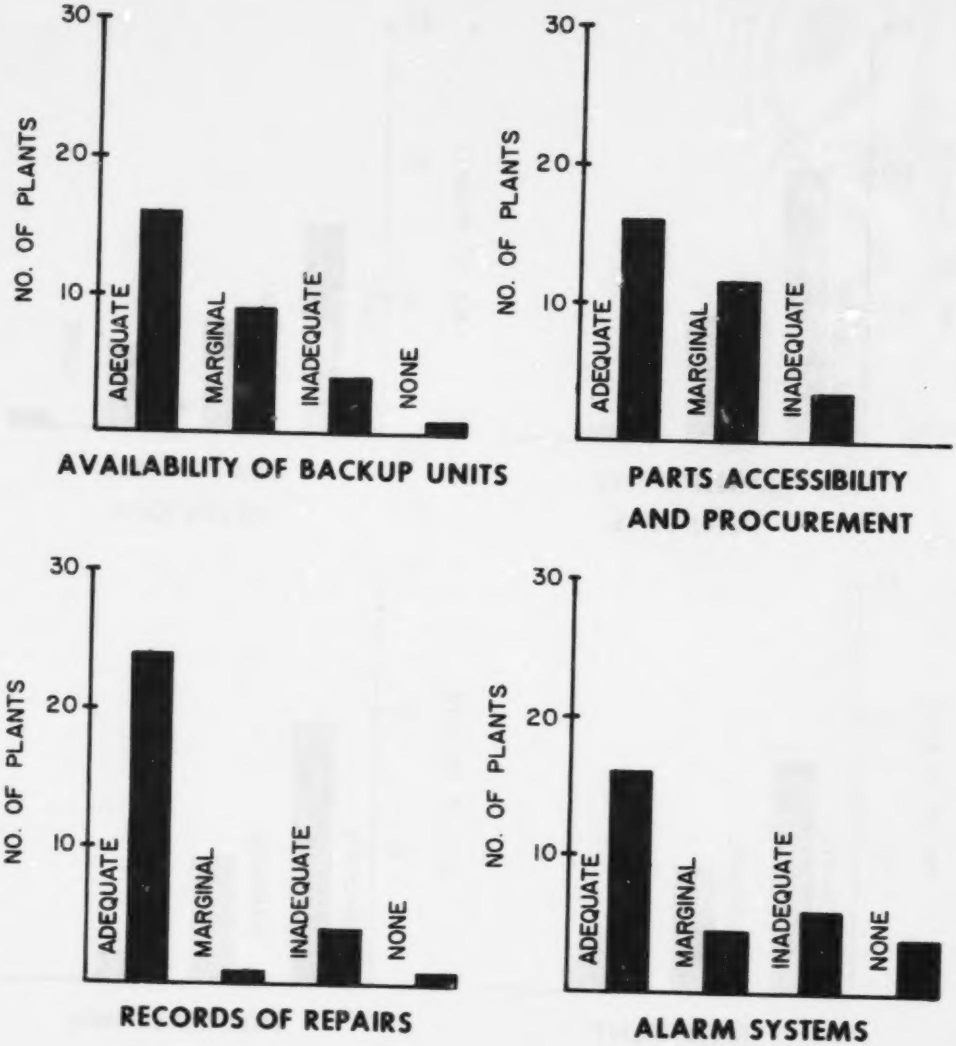


Figure 12. Operation and Maintenance Performance Indicators - Emergency Maintenance

commonly used spare parts, or were able to obtain them locally, delivery on major parts such as motors or impellers was often on the order of months. Such parts do not fail frequently and are expensive; so storage on-site was not practical. Therefore, the prolonged delivery times have been responsible for periods of poor plant performance.

SECTION 6

PRIORITY LISTING OF PROBLEMS

The ranking tables prepared for each of the preliminary evaluation plants, included as Appendix B, set forth the major problems noted at each facility. Since the majority of the data were collected during the 30-plant preliminary evaluation phase, these data form the basis for the major conclusions. Table 3, Plant Evaluation Summary, presents a priority listing of ten factors which most frequently and severely affect biological treatment plant performance. The top ten causes have been taken from the earlier discussed Weighting and Ranking tables prepared for each of the 30 preliminary evaluation plants. The total number of points assigned to each of the problem areas and the number of times that each factor was determined to be the most critical cause of treatment problems is also indicated. Other plant performance limiting problems, which were not included among the ten major problems, are set forth in Table 4. These are listed in order of decreasing adverse impact on performance according to the number of points accumulated for each problem on the 30 weighting and ranking tables.

Table 3 shows that the most significant cause of performance problems was the lack of application of treatment concepts and unit operation testing in controlling the biological process. This factor was ranked as the most severe deficiency at four of the 30 plants investigated. The third-ranked cause of performance problems, namely, the lack of an adequate process control testing program, is closely related to the first-ranked problem. A significant number of treatment facilities, especially those employing a suspended growth process, did not employ a process testing program. Specifically, standard unit operation control tests, such as mixed liquor suspended solids, mixed liquor dissolved oxygen, mixed liquor settleable solids, and return sludge suspended solids, were seldom or never conducted at plants studied. Furthermore, important operating parameters, including sludge volume index (SVI), food-to-microorganism ratio (F/M) and mean cell residence time (MCRT), were usually not determined. Without testing procedures as described above, effective process control is not likely.

Of noteworthy importance is the fact that the level of knowledge of the individual staffs at the various plants concerning wastewater treatment fundamentals was judged to be less of a problem than was the application of this knowledge. This situation is illustrated by the eighth place ranking that treatment understanding has been assigned. In many cases, the operators were familiar with process control tests and the application of concepts to process control, but exercised little or no process control in their operations. Therefore, although two of the highest ranked problem areas were associated with process control, it appears that the lack of unit operation testing and process control are not necessarily a result of inadequate training or comprehension

TABLE 3. PLANT EVALUATION SUMMARY
(Ten Problems Most Frequently Encountered)

Nature of Problem	Cause	Total Points	Times Ranked No. 1
Operation	Operator application of concepts and testing to process control	49	4
Design	Infiltration/inflow	44	4
Operation	Process control testing	36	-
Operation	O&M manual adequacy	34	-
Design	Industrial loading	19	1
Operation	Training	18	-
Design	Hydraulic loading	17	2
Operation	Treatment understanding	15	1
Design	Process controllability	15	1
Design	Sludge treatment	14	3

TABLE 4. PLANT EVALUATION SUMMARY
(Other Problems Encountered)

Nature of Problem	Cause	Total Points	Times Ranked No. 1
Operation	Process control technical guidance	14	-
Design	Unit design adequacy-aerator	14	1
Operation	Performance monitoring	14	-
Maintenance	Spare parts inventory	13	-
Design	Organic loading	12	4
Administration	Plant staff - number	11	2
Design	Unit design adequacy - disinfection	11	1
Maintenance	Preventive maintenance - lack of program	10	1
Administration	Plant administrators - familiarity with plant needs	10	1
Administration	Plant staff - plant coverage	10	-
Maintenance	Maintenance - manpower	10	-
Design	Unit design adequacy - primary	10	-
Design	Sludge wasting and return	9	1
Design	Flow proportioning to units	9	-
Maintenance	Critical parts procurement	8	-
Design	Lack of standby units for key equipment	8	-

(continued)

TABLE 4. (continued)

Nature of Problem	Cause	Total Points	Times Ranked No. 1
Design	Plant inoperability due to weather	8	-
Administration	Insufficient funding	7	1
Operation	Equipment malfunction	7	-
Maintenance	Preventive maintenance - references available	6	-
Design	Unit design adequacy - process flexibility	6	-
Design	Submerged weirs	6	-
Maintenance	Equipment age	5	-
Maintenance	Housekeeping practices	5	-
Design	Alternate power source	5	-
Maintenance	Maintenance scheduling and recording	4	-
Administration	Plant staff - productivity	4	-
Administration	Plant staff - motivation	4	-
Design	Plant location	4	-
Design	Lack of unit bypass	4	-
Design	Ultimate sludge disposal	3	-
Maintenance	Emergency maintenance - technical guidance	3	-
Administration	Plant administrators - policies	3	-
Design	Return process stream loading	3	-
Operation	Shift staffing adequacy	3	-
Design	Unit accessibility	3	-
Design	Toxic loading	3	1

(continued)

TABLE 4. (continued)

Nature of Problem	Cause	Total Points	Times Ranked No. 1
Administration	Plant staff - wages	3	-
Operation	O&M manual - use by operators	2	-
Maintenance	Emergency maintenance - staff expertise	2	-
Administration	Plant staff - supervision	2	-
Design	Alarm systems	2	-
Design	Flow backup	2	-
Operation	Certification level of operators	2	-
Administration	Personnel turnover	2	-
Operation	Education level of operators	1	-
Design	Process automation - control	1	-
Design	Process automation - monitoring	1	-
Design	Seasonal variation in loading	1	-
Administration	Plant staff - working conditions	1	-

in these areas, but rather the lack of application of (or inability to apply) learned techniques. Although the reasons for this condition have not been identified, it is believed that a basic lack of interest in, or incentive for, process control underlies the problem. Perhaps a disbelief in the merits of process control techniques by the operator contributes to the problem. Also, treatment knowledge notwithstanding, the individuals operating the majority of treatment plants studied in this project, especially the smaller ones, were inclined to be maintenance oriented rather than process oriented. In other words, the attention of the operator was directed at keeping the plant operating, rather than keeping the process at high performance levels.

The second most frequent cause of performance problems at the thirty preliminary evaluation plants was determined to be infiltration/inflow. Although constant hydraulic overloading was considered to be justification for elimination of a plant from further study at the outset of the project, periodic surging as a result of excessive infiltration/inflowwas found to exist at a majority of the facilities visited. The topographic and meteorological nature of the four states surveyed make infiltration/inflow a widespread problem. For this reason, preliminary evaluations were conducted at a number of plants which, although they were not constantly hydraulically overloaded, experienced severe fluctuations in flow rate. (See "Research Approach Section"). The most notable and significant process problem caused by these surges was "washout" of the suspended growth systems as a result of a loss of solids from the final clarification stage during high flow periods. Also, the increases in extraneous water caused the raw wastewater to become dilute and the biological processes, both fixed and suspended, were loaded at much less than optimal levels.

Inadequacy of (or lack of) a comprehensive operations and maintenance manual was ranked as the fourth most severe cause of plant performance problems. This condition existed at a large number of plants. However, the fact that this particular item was never judged to be the most serious cause of problems at any given plant indicates that although the situation is widespread, the measurable adverse impact on plant performance often is moderate. As noted previously, the weighting and ranking process is necessarily subjective. With respect to operations and maintenance manuals, the observation of the investigating team was generally that a competent plant staff could overcome the inadequate manual through the use of available manufacturer's equipment information, as-built plans, readily obtainable operations publications as provided by EPA, and wastewater treatment technology texts. However, the poor quality of most plant O&M manuals undoubtedly has contributed to the general de-emphasis of process control.

The fifth most frequently observed cause of performance problems was industrial loading. It is noted that there is a significant break in total points between the fourth and fifth problem. Although industrial loading was ranked as the number one cause of performance problems at one facility, the total number of assigned points indicates that a minority of plants were adversely affected by industrial wastewaters. Generally, these industrial wastewaters caused fluctuating flows and pollutant loads as a result of intermittent discharges. In addition, the nature of the industrial wastewaters was usually such that the problems resulted from excessive compatible pollutant levels, rather than incompatible or toxic wastes. In this study, types of industries responsible for process upsets and plant overloading included food processing, dairy, and textile manufacturing and dyeing.

Inadequate training was determined to be the sixth ranked cause of performance problems. At the plants evaluated, most of the personnel had received some form of training, such as the Sacramento or Clemson wastewater treatment courses. In six cases (as determined by a weight of 2 or 3 in the weighting and ranking process) inexperienced personnel with little or no training were responsible for the operation of primarily small (<1 mgd) but relatively complex plants, most of which employed suspended growth systems. The relatively low point total suggests that the cause was not widespread and also supports the hypothesis that the problem of inadequate process control is related more to application of control concepts than to a lack of knowledge of techniques.

Three causes of performance problems were found to be directly associated with characteristics of the plant service area. Two of these factors, infiltration/inflow and industrial loading, were discussed previously. Hydraulic loading, which refers to the relationship between actual plant flows and design flows, was the number one cause of performance problems at only two facilities and accumulated a total of only seventeen points. Its overall impact on plant performance was moderate. Although hydraulic loading and infiltration /inflow are closely related, a facility may be adversely affected by infiltration/inflow although hydraulic overloading may not be a problem. Specifically, in some plants studied in this project infiltration/inflow resulted in a dilute wastewater, causing the biological system to be underfed and unstable. Direct impacts of hydraulic overloading consisted primarily of excessive process overflow rates, weir loading rates, and/or inadequate unit process detention times.

Process controllability and sludge treatment were ranked respectively as the ninth and tenth most frequently encountered causes of performance problems. Both of these factors are design related and indicate the need for improvements in design at several facilities. Inadequate process controllability included, as examples, the inability to vary rates of return sludge, recirculation of trickling filter effluent, and air input. As a result, the operator was unable to "tune" his treatment system to the varying demands which were placed on it by hydraulic and organic loading fluctuations.

The tenth ranked problem, sludge treatment, was the number one cause of performance problems at three of the preliminary evaluation plants. Those plants lacked adequate waste sludge handling, dewatering, or ultimate disposal facilities. All of the rational procedures for activated sludge process control use sludge wasting to set the control parameters (F/M, SRT, O_2 uptake). Therefore, if the operator's ability to waste sludge is determined by available equipment rather than process consideration, proper process control is not possible. Under the most severe conditions, a buildup of sludge in the system results in the loss of solids in the final effluent. It was found during this study that the latter condition is often erroneously diagnosed as sludge bulking.

In summary, the major factors found to inhibit treatment plant performance could be divided into three categories; operator oriented, design oriented, and service area oriented. Through the weighting and ranking procedure, the most widespread deficiency at treatment plants studied was found to be operator oriented. A sound process control program was notably absent at many plants. The service area problem was infiltration/inflow, and this of course could be corrected through inspection and repair of collection systems. Although design deficiencies and problems from industrial wastes were found to exist, in many cases the adverse effects could probably be minimized using sound process control techniques.

SECTION 7

OTHER INVESTIGATIONS - SPECIAL STUDY

Each preliminary evaluation was designed to identify various aspects of plant design, operation, maintenance, and administration that were adversely affecting plant performance. Data obtained during the studies indicate that poor sludge settleability, or sludge bulking, is a common problem among the various types of activated sludge processes. Bulking sludge interferes with plant performance and effluent quality by hindering solids settling and allowing excess solids to overflow the secondary clarifier weirs. It also subverts the controllability of an activated sludge process: sludge age, biomass loading, and mixed liquor concentrations cannot be directly controlled by sludge wasting when uncontrolled amounts of solids are leaving the system in the plant effluent.

Because of the direct adverse impact that sludge bulking has on treatment plant performance, and the widespread occurrence of the problem, a special study was conducted at a regional treatment facility, designated as Plant 32 in Appendix A. The plant had also been the subject of a preliminary evaluation study. The principal conclusion of the preliminary evaluation was that poor sludge settleability was limiting the performance of the system. Although some possible contributing factors to this problem were set forth in the preliminary evaluation report, the available data were not sufficient to support definitive conclusions. The plant, therefore, was considered an appropriate site to conduct an in-depth study of the bulking phenomenon. The study was undertaken to identify the direct cause of poor sludge settleability at this plant, and to recommend operational procedures for eliminating the problem.

The scope of the special study included, as a first step, a look at the conventional approaches to eliminating bulking. These included F/M control, aeration control, and selection of the operating mode for the activated sludge system (e.g., complete mix vs. contact stabilization). Secondly, the performance characteristics of the secondary clarifiers and sludge return capabilities were investigated in detail. Thirdly, microbiological studies were performed to identify the dominant filamentous organisms in the bulking sludge. By identifying these bacteria and determining the environmental conditions that favor their growth, the operator can formulate and implement a rational control strategy to eliminate them.

This study was performed over a period of about three months, from midwinter through early spring 1977. Historically, the winter months have been the period of the most severe sludge bulking problems at this particular facility. The time of year chosen for the study, therefore, allowed maximum opportunity to observe and evaluate the problem.

DESCRIPTION OF TREATMENT PLANT

The special study plant is a conventional activated sludge facility with the flexibility to be operated as a complete mix or contact stabilization process. It has an average design flow of 15,140 m^3/d (12.0 mgd). A process flow schematic is presented in Figure 13. The major treatment units are two circular primary clarifiers, two rectangular aeration tanks, two rapid sludge removal-type circular secondary clarifiers, four multi-media filter beds, a chlorine contact tank, and a post aeration basin. The multi-media filters were not in use during the study and, in fact, have not been used for any significant length of time since plant start-up in 1973. This has been primarily due to the high level of solids in the secondary clarifier effluent and the resultant rapid plugging of the filters. Under such conditions, the cycle time between backwashings becomes unreasonably short, and the filter system is basically inoperable.

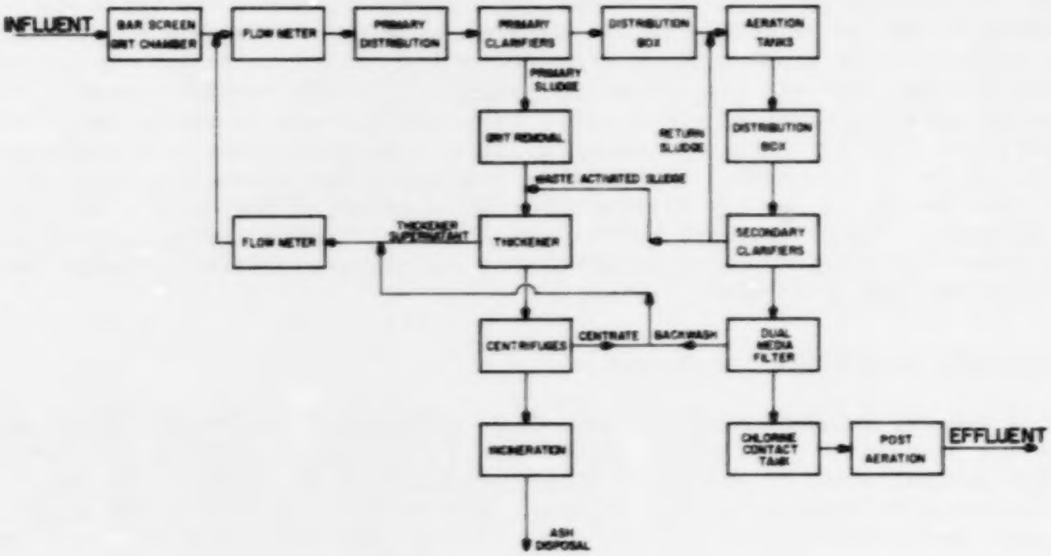

INFLUENT
BAR SCREEN GRIT CHAMBER
FLOW METER
PRIMARY DISTRIBUTION
PRIMARY CLARIFIERS
DISTRIBUTION BOX
AERATION TANKS
PRIMARY SLUDGE
GRIT REMOVAL
RETURN SLUDGE
DISTRIBUTION BOX
WASTE ACTIVATED SLUDGE
FLOW METER
THICKENER SUPERNATANT
THICKENER
SECONDARY CLARIFIERS
CENTRIFUGES
CENTRATE
BACKWASH
DUAL MEDIA FILTER
INCINERATION
CHLORINE CONTACT TANK
POST AERATION
EFFLUENT
ASH DISPOSAL

Figure 13. Schematic of Wastewater Treatment Facility

Primary sludge and waste activated sludge are handled by thickening, centrifugation, and fluidized bed incineration. Centrifuge centrate, filter backwash, and thickener overflow are returned to the head of the plant.

The treatment facility examined under the special study phase is not automated. All significant process control parameters are set by the operator including aeration rates, sludge return rates, and sludge wasting rates. The operator also controls the routing of flow through the plant such that complete mix activated sludge or contact stabilization is the treatment mode. A lighted graphic panel indicates important plant equipment and various interconnections. The status of operation of each item is indicated by signals at a control console. All major plant equipment may be controlled through the control panel or by localized control at each particular unit. Dissolved oxygen and pH probes are located in each of the two aeration tanks and provide continuous readout at the control panel for mixed liquor D.O. and pH. Totalizers indicate flows occurring in various components. All additional sampling and analysis for process control is done manually. Samples are obtained daily from the primary distribution chamber and secondary clarifiers for BOD_5 and suspended solids analyses. Daily samples are obtained from each aeration tank and analyzed for suspended solids and volatile suspended solids. Therefore, between the automatic sensing devices and the plant laboratory, all information necessary for process control may be obtained.

From a review of the basis of design, the various treatment units at the plant are considered adequately sized and equipped to handle the flows and loadings. When properly operating, the process should be capable of providing the degree of treatment required by the discharge permit. Flexibility is provided in that dissolved oxygen may be controlled via the variable speed aerators, mixed liquor concentrations and sludge age may be controlled through adjustment of sludge return and wasting rates, and the process flow configuration may be varied between the complete mix and contact-stabilization modes. With this amount of process flexibility, optimization of the process should be possible. However, sludge bulking can subvert the entire process by thwarting proper operation of the aeration tanks, secondary clarifiers, sludge return system, and multi-media filters.

PRELIMINARY EVALUATION CONCLUSIONS

A general conclusion of the referenced preliminary evaluation report was that the problem of poor solids separation in the final clarifiers resulted in a high concentration of suspended solids passing over the weirs. The condition was attributed to sludge bulking. Microscopic analysis of the mixed liquors during the bulking period showed that a large percentage of the microbial population were filamentous bacteria types which cause sludge settleability problems. At the time of the preliminary evaluation, plant operating personnel had not been able to determine the cause of the sludge bulking, or to successfully prevent the problem.

Possible causes for the sludge bulking problem as listed in the preliminary report included:

1. Large variations in influent organic strength.

2. Frequent change in process configuration.

3. Insufficient process control (F/M, sludge wasting, sludge return).

The report concluded that a more consistent level of organic loading to the aeration system should be achieved. Recommendations to accomplish this stability included:

1. Development of a thorough knowledge of the contributing industrial wastewater.
2. Establishment of a schedule of the variation in industrial flows and strengths.
3. Installation of a holding system to equalize industrial waste loadings.
4. Elimination of the sources of infiltration.
5. Addition of chemical flocculants, such as lime, to the primary clarifier system to aid in settling during periods of high pollutant loadings.

Also included in the preliminary report was the recommendation that the media filtration system be operated according to the design intent. It was recognized that this was not possible under the conditions created by sludge bulking because of rapid clogging in the filter beds.

Bulking activated sludge is sludge that occupies excessive volume after sufficient time has been allowed for settling. The effect of filamentous bacteria in increasing the bulk of activated sludge is primarily mechanical; that is, the filaments protrude from the sludge particles and physically hold them apart.

Filamentous organisms are of two basic types: bacterial, which are most prevalent in municipal sewages; and fungi, which are usually most prevalent in industrial wastewaters. The more common bacteria are *Sphaerotilus natans*, *Bacilus cereus*, *Thiothrix* and *Beggiatoa*, while the more common fungi are *Geotrichum*, *Candida* and *Trichoderma*.

There are many suggested causes for sludge bulking. Some of the commonly cited causes are low dissolved oxygen concentrations in the aeration tanks, excessively low or high food to microorganism ratios, high sulfide levels in the wastewater (indicative of septic wastewater), and extensive variations in organic loadings to the system. Many industrial wastes also can stimulate growth of filamentous organisms by causing fluctuating or excessively high organic concentrations, which result in low dissolved oxygen levels, creating the ideal conditions for bulking sludge.

Many remedies have been proposed for controlling bulking sludge. Some of these include mixed liquor chlorination and hydrogen peroxide treatment, increasing the dissolved oxygen of the return sludge, adding flocculant aids, and optimizing the sludge loading rate. All but the last of these treat the effect rather than the cause and, as such, are only temporary. This has been demonstrated at numerous treatment plants where bulking problems have returned after attenuation of the chemical additions. An approach more likely to meet with long-term success would consist of isolating and identifying the filamentous organisms and adjusting operating conditions to hinder their growth.

MAINTENANCE OF SLUDGE SETTLEABILITY BY F/M CONTROL

A major problem identified at the plant during the earlier preliminary evaluation study was the fluctuating organic strength of the incoming wastewaters. This condition was felt to be due to the operation of food processing industries in the service area. Since there are no equalization facilities at the plant, the organics pass on to the primary sedimentation and aeration systems, the result being variations in the F/M ratio. From the microbiological standpoint, this situation represents instability in the system, and can provide an environment that favors the filamentous bacteria associated with sludge bulking. A logical first step in a corrective program, therefore, was to hold the F/M within a reasonable range to promote the growth of a good floc-forming bacterial population.

Primary effluent BOD5 is normally not monitored at the facility. Therefore, for purposes of this study, the plant superintendent was asked to start monitoring that parameter on a daily basis. A program was started to maintain the F/M in the aeration system at approximately 0.3 Kg BOD_5/day/Kg MLSS by controlling MLSS through daily sludge wasting. Thus, for any given primary effluent BOD_5 concentration, a corresponding MLSS concentration in the aeration tanks and volume of sludge to be wasted on that day were set. The relationship is shown graphically in Figure 14. Since the sludge volumes were to be determined solely on the basis of primary effluent BOD_5, the blanket level in the secondary clarifier was to be controlled by recirculation rate.

Attempts to control F/M met with immediate difficulty. The calculations called for a lower sludge wasting rate than previously in effect at the plant. However, attempts to decrease this rate resulted in rising sludge blankets in the secondary clarifiers. If, during a bulking period, the sludge recirculation rate was increased in order to lower the sludge level, the opposite effect was observed. Increasing the sludge recirculation rate actually resulted in the sludge blanket moving closer to the clarifier surface and, ultimately, the loss of solids over the clarifier weirs. Plant operating personnel indicated that past attempts to control the aeration reactor environment by adjusting the return sludge flow had failed because of similar physical limitations imposed by the clarifiers.

This first phase of the special study, therefore, led to the conclusion that control of the organic loading on the aerated biomass could not be used as a means to operate out of the bulking conditions. This is not to say, however, that F/M control would not be a viable control option when the activated sludge exhibits good settling properties. Proper controls under that condition could prevent the bulking. It should be noted that influent BOD_5 fluctuations observed during this investigation were of a much lesser magnitude than those observed during the earlier study. Thus, the problem of varying F/M in the aeration system was somewhat attenuated during the special study. The operator indicated, however, that this was probably a temporary phenomenon as similar dampening of BOD$_5$ fluctuation had occurred in the past.

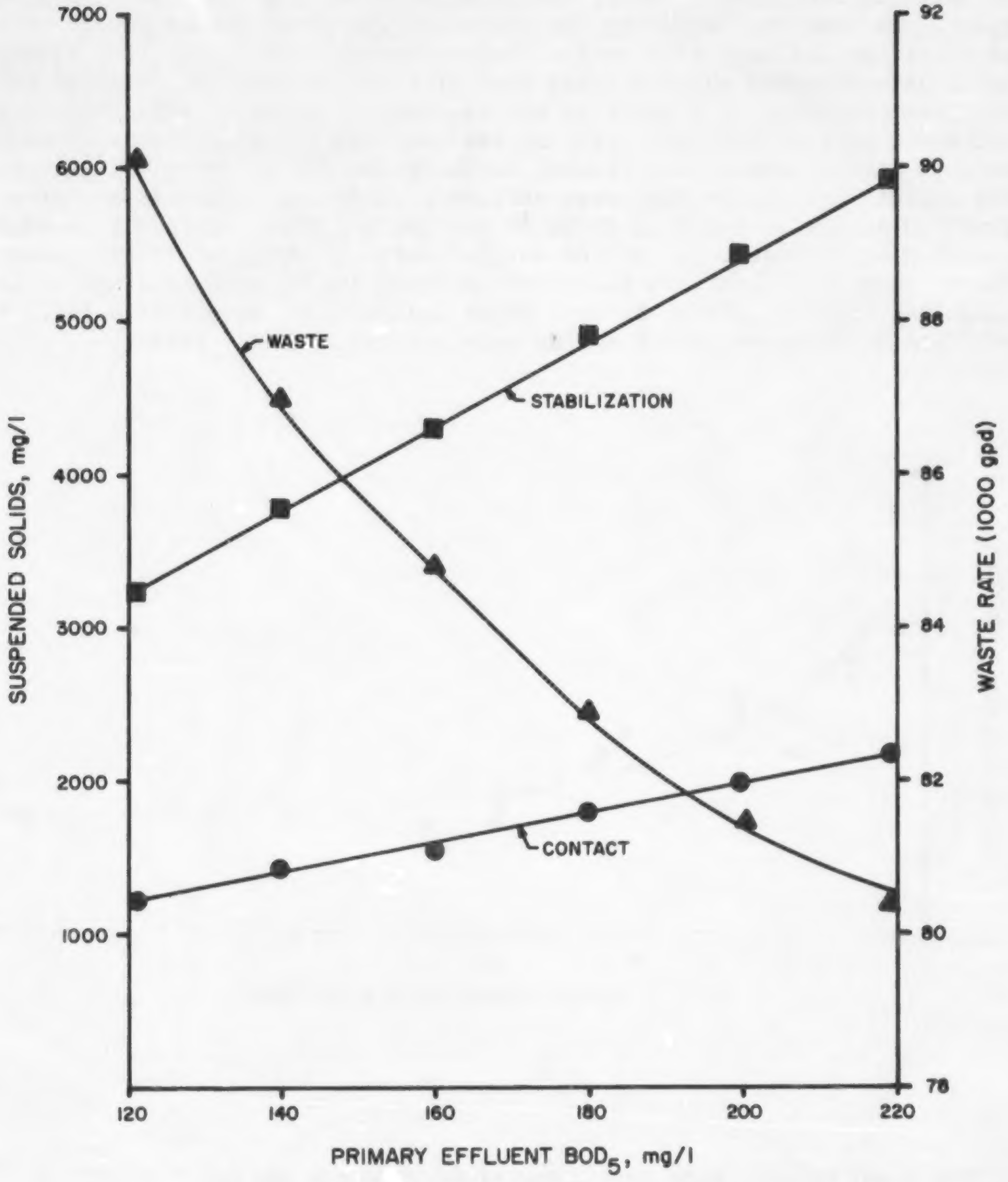
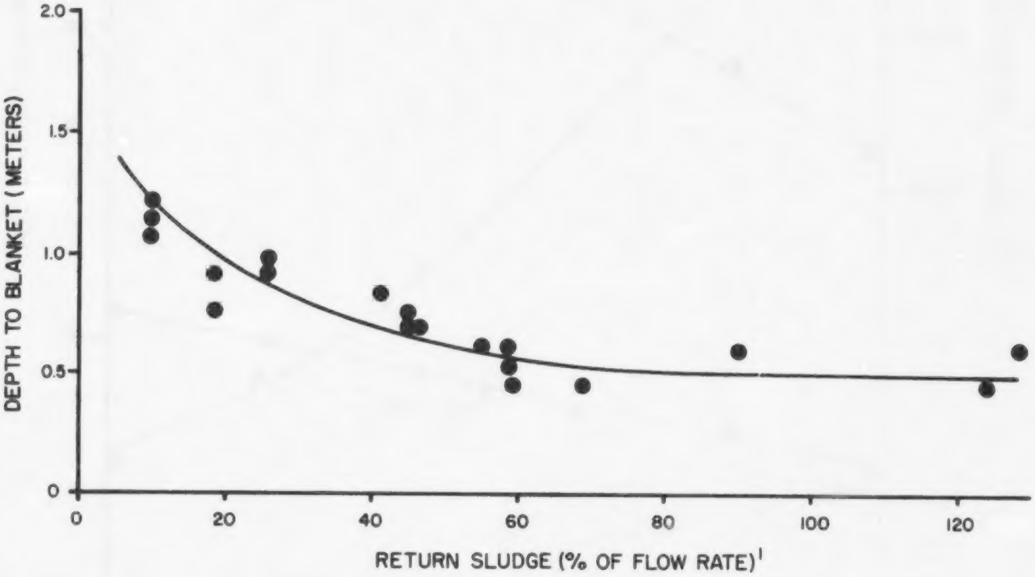


Figure 14. Recommended Reactor Concentrations and Waste Rates

SECONDARY CLARIFIER CHARACTERIZATION

Since initial attempts at process control indicated that limitations were imposed by the secondary clarification system, a decision was made to study the settling and sludge removal characteristics of the clarifiers in greater detail. In order to determine the effect of increased return sludge rates and clarifier influent flow on the sludge blanket level, clarifier blanket depths were measured while varying each of those parameters. Results of this study are presented in Figures 15 and 16. Return rates of less than 30 percent and clarifier influent rates of less than 18,925 m^3/d (5.0 mgd) were found to permit comfortable blanket depths which did not result in a noticeable solids loss in the secondary effluent. Moderate solids losses were experienced at return rates of 40 to 60 percent and flows of 18,925 to 24,602 m^3/d (5.0 to 6.5 mgd). Excessive solids losses occurred at return rates of greater than 70 percent and flows greater than 30,280 m^3/d (8.0 mgd). It was found that when the sludge blanket depth reached 0.46 meters (1.5 feet) beneath the surface, excessive solids were carried over the weirs.



[1] AVG. PLANT INFLUENT FLOW RATE DURING STUDY = 15,140 m^3/d (4.0 mgd)
FLOW RANGE = 14,000 to 15,897 m^3/d (3.7 to 4.2 mgd)

Figure 15. Effect of Return Sludge Rate on Blanket Depth

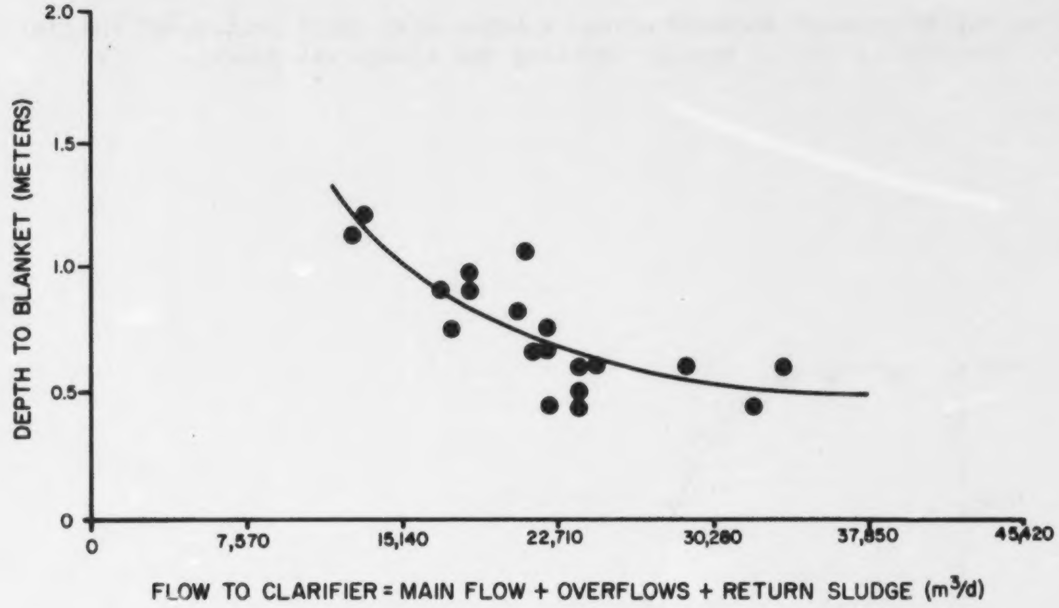


Figure 16. Effect of Influent Clarifier Flow on Blanket Depth

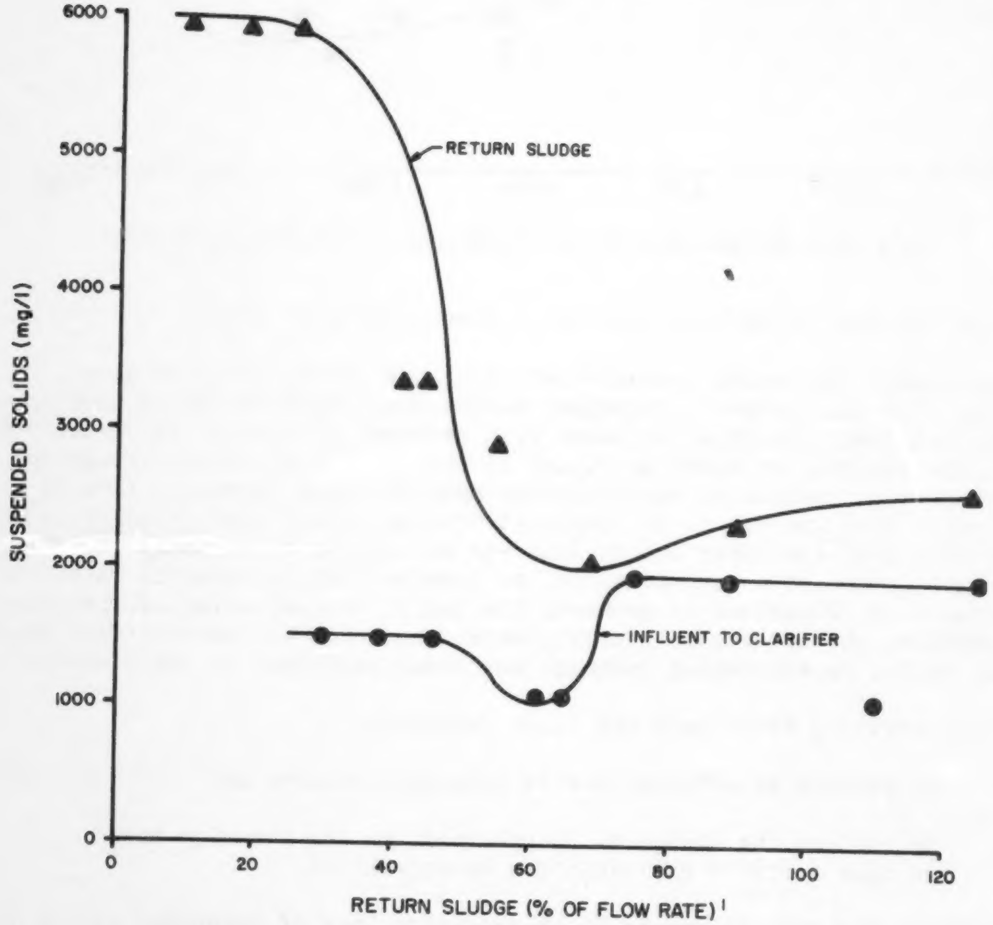
The sludge thickening characteristics of the clarifiers were also analyzed. For this purpose, suspended solids concentrations for return sludge flow and secondary clarifier influent were measured at various sludge return rates. The results, as shown in Figure 17, indicate that return sludge concentrations were reduced as recirculation pumping rates increased from 30 to 70 percent. This was due to the physical removal of the lower blanket solids and the fact that the upper solids flux was not adequate to transport solids to the tank bottom at a rate equal to, or greater than, the removal rate. At return rates of 70 percent or greater, the solids concentration of the clarifier underflow was not significantly greater than that of the clarifier feed. In other words, no thickening function was being performed by the clarifier.

Final settling tanks have two basic functions:

1. To produce an effluent low in suspended solids, and

2. To thicken the sludge to be returned to the aeration tanks so that a stable F/M ratio can be maintained.

Inadequate thickening can result in an excessive loss of suspended solids in the final effluent and a loss of biological process control, since mean cell residence time and aeration tank solids concentration cannot be effectively controlled. This condition was found to exist at the special study plant. Solids flux through the final clarifiers was determined in order to allow a comparison to a well-operated clarification system. Solids flux refers to the rate of solids passage downward across a horizontal cross section of the clarifier. The flux is due to gravity settling and sludge withdrawal.



[1] AVG. INFLUENT FLOW TO PLANT DURING STUDY = 15,140 m^3/d (4.0 mgd)
FLOW RANGE = 14,000 to 15,897 m^3/d (3.7 to 4.2 mgd)

Figure 17. Relationship of Return Sludge Rate to Clarifier Solids Concentrations

Solids flux due to gravity settling equals the product of the downward particle velocity and the concentration of solids at a given depth. It can be determined in the laboratory by performing a settling test on a representative sample of sludge. The results of a settling test using clarifier influent are shown in Table 5. Settling velocity and solids flux as a function of sludge concentration as shown in Figures 18 and 19. A maximum settling velocity of 0.40 cm/min (0.013 ft/min) was observed at a suspended solids concentration of 3,200 mg/l. Maximum flux also occurred at a concentration of 3,200 mg/l, with a secondary peak occurring at 6,000 mg/l. Maximum gravity flux was 14.6 to 19.5 $Kg/m^2/d$ (3 to 4 $lb/ft^2/day$).

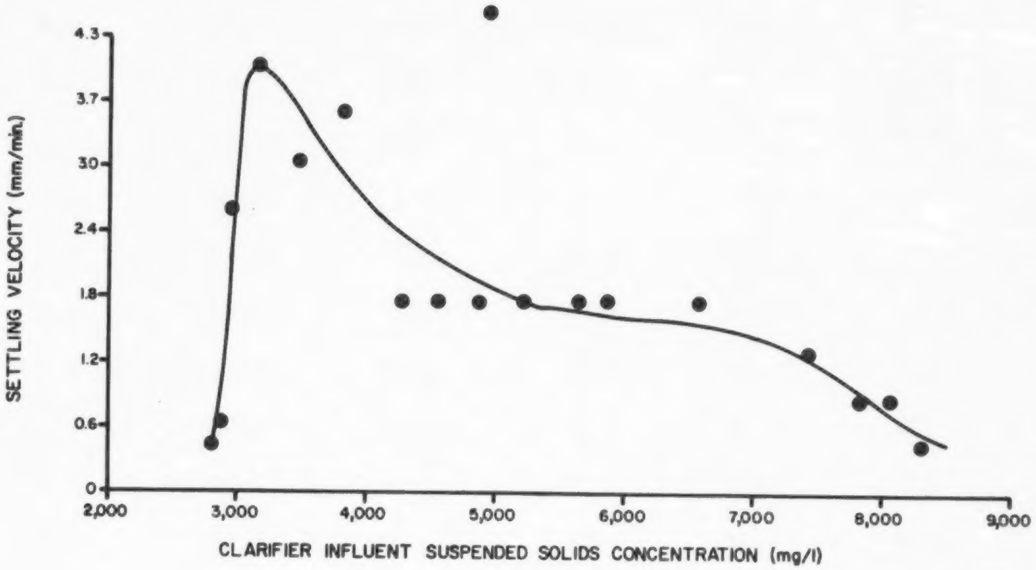


Figure 18. Gravitational Settling Velocity As a Function of Suspended Solids Concentration

Solids flux as a result of sludge removal from the clarifier is simply a function of the surface area of the clarifier and the return rate, and represents a draw down of the sludge blanket due to physical removal of liquid from the bottom of the clarifier. This flux can be calculated for the clarifiers at various suspended solids concentrations. This relationship is shown graphically in Figure 20. The total solids flux is the result of adding the curves shown in Figures 19 and 20. Total solids flux as a function of suspended solids concentration, then, is shown in Figure 21. The resultant flux is observed to be only slightly greater than the flux due strictly to sludge withdrawl. This indicates that the downward transport of solids due to sedimentation was poor. In order to effect acceptable thickening, the flux due to

TABLE 5. MIXED LIQUOR SETTLING VELOCITY AND GRAVITY FLUX

Time Min.	Settled Volume ml/1	MLSS mg/1	mm/min.	Ft/min.	Solids Flux Kg/m^2/d	Solids Flux lb/ft^2/day
0	1000	2825	0.44	.0015	1.95	0.4
10	990	2850	0.67	.0022	2.93	0.6
20	975	2897	0.67	.0022	2.93	0.6
30	960	2943	2.67	.0088	11.23	2.3
40	900	3139	3.96	.013	18.07	3.7
50	810	3488	3.05	.010	15.63	3.2
60	740	3818	3.56	.012	19.53	4.0
70	660	4280	1.78	.0058	10.74	2.2
80	620	4556	1.78	.0058	11.72	2.4
90	580	4870	1.78	.0058	12.70	2.6
100	540	5231	1.78	.0058	13.18	2.7
110	500	5650	1.78	.0058	14.65	3.0
120	460	5885	1.78	.0058	15.14	3.1
130	420	6570	1.34	.0044	12.70	2.6
140	390	7434	0.89	.0029	9.77	2.0
150	370	7847	0.89	.0029	10.25	2.1
160	350	8071	0.44	.0015	5.37	1.1
170	340	8309	0	0	0	0
180	340	8309	0	0	0	0

gravity (solids sedimentation) would have to be significantly increased.

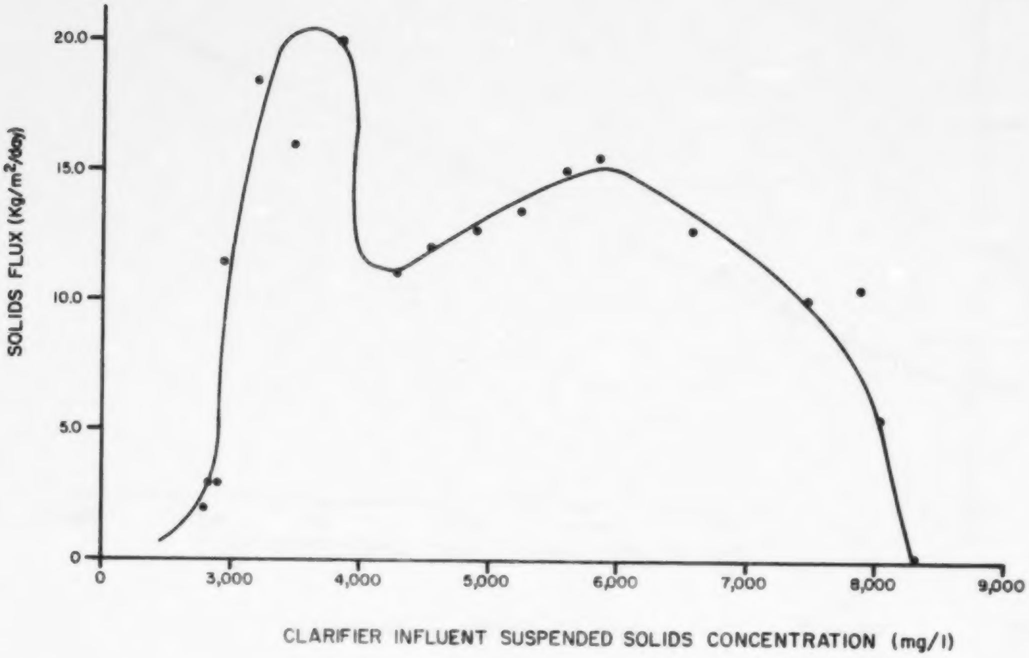


Figure 19. Transport of Solids Due to Gravity Sedimentation

A summary of the final clarifier studies considers the following major points:

1. Maintenance of a stable biological system depends upon the ability to control MLSS in the aeration tanks through appropriate adjustment of return sludge mass.
2. Sludge wasting and return rates were found to be limited by sludge settleability and resultant clarifier performance. Parameters calculated to achieve best performance in the aeration system cannot be maintained without severe solids losses over the clarifier weirs.
3. Solids flux values measured for the sludge were found to be much less than those required for good thickening in the clarifier.
4. Sludge return rates of 60 percent with corresponding clarifier influent flow rates of 22,710 m^3/d (6.0 mgd), or greater, result in a severely expanded sludge blanket and excessive solids carryover.

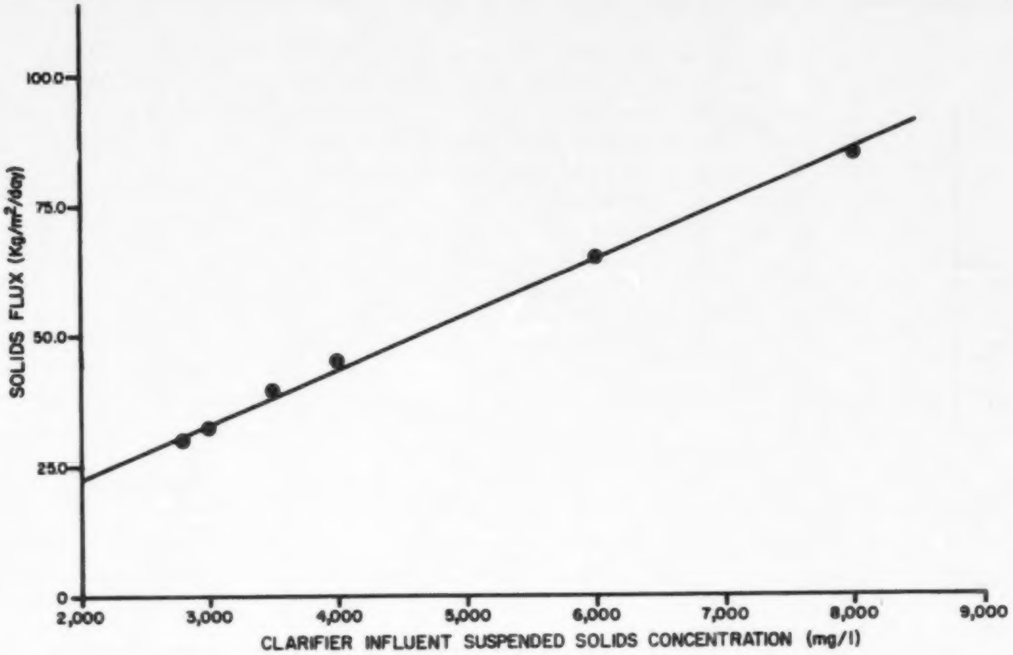


Figure 20. Transport of Solids Due to Sludge Withdrawal

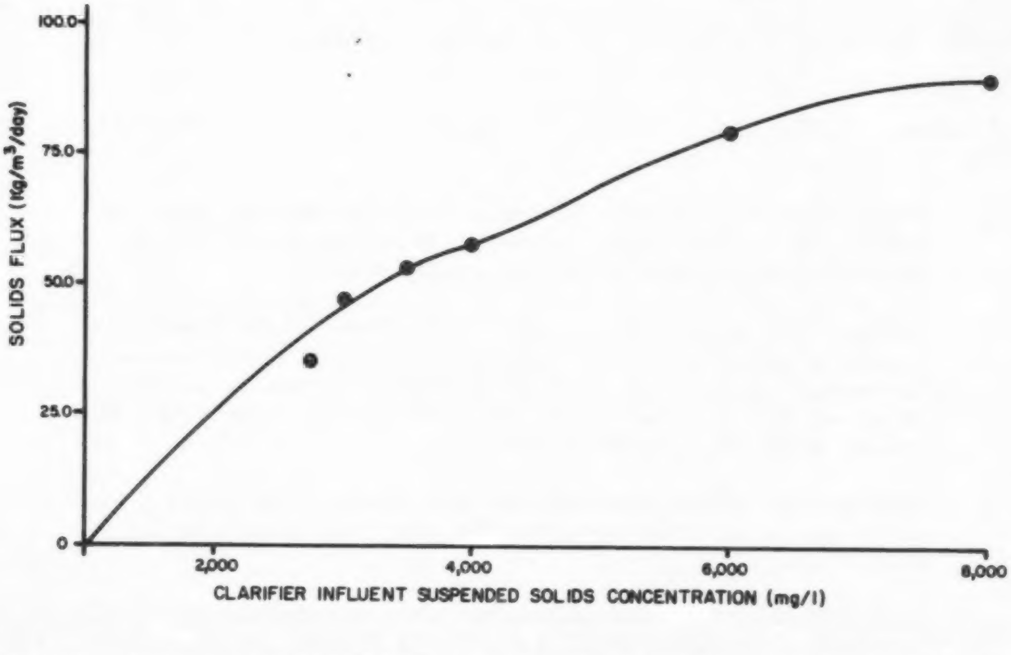


Figure 21. Transport of Solids Due to Gravity Sedimentation and Sludge Withdrawal

MICROBIOLOGICAL STUDIES

The previously discussed clarifier studies proved that sludge settleability was the major obstacle to efficient process control at the plant. Microscopic observations and discussions with the plant superintendent indicated that filamentous bacteria were present in the sludge. The quantity of these organisms had been observed to vary with the time of year, being the most predominant during the winter. Unfortunately, the identification of a filamentous bulking situation does not conclusively suggest a remedy. The identification of the organism(s) responsible is the first step in curing the bulking problem, followed by the identification of those factors in the microbial environment that can stimulate or support their growth. If one or more such factors exist in the treatment plant, the control or removal of them can effect a permanent solution. A temporary control alternative is to destroy the filamentous bacteria using oxidants such as hydrogen peroxide or chlorine.

A program was undertaken to identify and isolate the filamentous bacteria present in the sludge. Microscopic studies to determine the in-situ characteristics of the filamentous cells were performed. Characteristics of the predominant filamentous organisms are listed in Table 6. A cross-check of these characteristics with bacteriological keys indicated Thiothrix to be the predominant organism at the time of the study. Sphaerotilus were also identified in significant numbers.

TABLE 6. MICROBIOLOGICAL CHARACTERISTICS OF FILAMENTOUS CELLS IN SLUDGE AT SPECIAL STUDY PLANT

Characteristics of Predominant Organism:

1. Trichomes existing in lengths up to 700 u
2. Sheath apparent but not distinct
3. Occasional but infrequent jerking motility
4. No branching, some attached unicellular organisms
5. Occasional rosette formation
6. Cylindrical cells, 1 to 2 u wide by 2 u long
7. Many intracellular deposits; tests indicate sulfur granules, no iron
8. Cell size differentiation between base and tip, rod-shaped cells on tip of trichomes

Characteristics of Secondary Organisms:

1. Trichomes several hundred microns long, sometimes curved on tip
2. Very distinct sheaths
3. Some deposition in sheath, not identified

To further support the findings that *Thiothrix* was the predominant organisms and that *Sphaerotilus* was also present, attempts were made to isolate these bacteria using selective nutrient agars as growth media. Colonies characteristic of *Sphaerotilus* were readily grown on a combination of standard nutrient agar and trypticase soy (TCS) agar. These colonies were identified as *Sphaerotilus* according to the methods of Farquhar and Boyle (1971). *Thiothrix* was not successfully isolated on this medium.

A second isolation procedure was also followed. This procedure, documented by Liu, Kwasniewska, and Cohen (1977), is based on research that has shown filamentous organisms to be much more tolerant of certain toxic agents, specifically, n-amyl alcohol in this case. Samples of aeration basin mixed liquor were spiked with n-amyl alcohol and streaked on modified nutrient agar plates, fortified with sodium acetate and glucose. Two distinct types of filamentous colonies were isolated. When examined, one was found to be *Sphaerotilus*. The other appeared to be *Thiothrix.* Since intracellular sulfur deposits are characteristic of *Thiothrix*, tests were performed to detect their presence. The results were positive, lending further evidence of the isolation and identification of *Thiothrix*. The literature indicates that *Thiothrix* has generally not been grown in pure culture. In light of the relative newness of the n-amyl alcohol procedure, further study would be recommended to prove conclusively the apparent isolation of *Thiothrix* seen in this study.

In summary, microbiological investigations of the bulking sludge during February and March 1977 indicated *Thiothrix* to be the predominant filamentous bacteria present. A second genus, *Sphaerotilus*, was also identified. The microscopic identifications were based on morphological characteristics and associated traits such as the degree of motility and the content of cell vacuoles. This existence of *Thiothrix* and *Sphaerotilus* was further supported by isolation and examination of the filamentous organisms in pure culture.

HYDROGEN SULFIDE STUDIES

Since the microbiological analyses indicated *Thiothrix* to be the predominant filamentous form during periods when bulking was most severe, the next step was to determine those factors in the treatment plant environment which were responsible for the selective proliferation of that organism. *Thiothrix* oxidizes hydrogen sulfide to sulfur with subsequent intracellular deposition of sulfur. The microorganisms use this oxidation as a source of energy, and hydrogen sulfide concentrations of 0.5 mg/l, or even less, can stimulate the growth of *Thiothrix*. Consequently, eliminating and preventing the formation of hydrogen sulfide is the key to eliminating *Thiothrix*. This organism has been observed to grow well in the F/M range of 0.2 to 0.4 Kg BOD_5 /day/Kg MLVSS (Farquhar and Boyle, 1971). Since this is the optimum range for activated sludge operation, corrective action in addition to F/M control is necessary for eliminating the *Thiothrix* population.

Hydrogen sulfide was found in varying concentrations at a number of points in the treatment train. Table 7 summarizes the results. As indicated, no detectable hydrogen sulfide concentration was found in the effluent from either primary clarifier. The concentration in the raw sewage is probably destroyed by the aerating effect of the lift pumps at the head of the plant.

TABLE 7. HYDROGEN SULFIDE CONCENTRATIONS

Sample	H_2S (mg/l)*
Raw Influent	0.1
Primary Effluent Clarifier No. 1	<0.1
Primary Effluent Clarifier No. 2	<0.1
Secondary Effluent	<0.1
Centrate	0.9
Sludge Thickener Overflow	0.3

* Limit of detection = 0.1 mg/l

Dissolved oxygen concentrations of greater than 5 mg/l in the primary clarifier influent were commonly measured during the study. Thus, the hydrogen sulfide supporting the growth of Thiothrix was apparently not associated with the influent sewage. Hydrogen sulfide in the thickener overflow and centrifuge centrate, was diluted to less than 0.1 mg/l when these flows were recycled to the head of the plant and combined with the raw wastewater.

The sludge samples taken from the secondary clarifiers were also analyzed for hydrogen sulfide. Samples were taken from 15 cm (6 inches) above the clarifier bottom at approximately 1.2 meters (4-foot) intervals measured radially from the center of the clarifier. A profile on sludge hydrogen sulfide concentrations from the center to the outer wall of one of the final clarifiers is shown in Figure 22. The hydrogen sulfide concentrations at the points of sludge withdrawal were generally lower than the concentrations found between the sludge withdrawal ports. The average concentration measured was 16.8 mg/l and concentrations as high as 34.6 mg/l were measured between the ports. Across the clarifier bottom all sulfide concentrations in the sludge were above that level which can stimulate the growth of Thiothrix.

As the point of sampling was moved up from the clarifier bottom, the sulfide concentration rapidly fell off. At an elevation of 30 cm (1 foot) above the clarifier bottom, the sludge concentration varied from <0.1 mg/l (the detention limit) to 0.5 mg/l.

For comparison, hydrogen sulfide concentrations were measured at the bottoms of secondary clarifiers at several other treatment plants. Figure 23 shows the results for a conventional activated sludge plant in Pennsylvania. At this plant, no trend of sulfide concentrations as a function of position with respect to sludge withdrawal ports could be identified. However, the 2 mg/l average sulfide concentration was considerably lower than that observed at the special study plant. Since design sludge detention times at both plants were similar, this parameter could not account for the higher sulfide concentrations in the special study plant sludge.

The only significant difference found between the special study plant and the other activated sludge plants with similar clarifiers is related to the sludge withdrawal mechanism. In the special study facility, V-ploughs

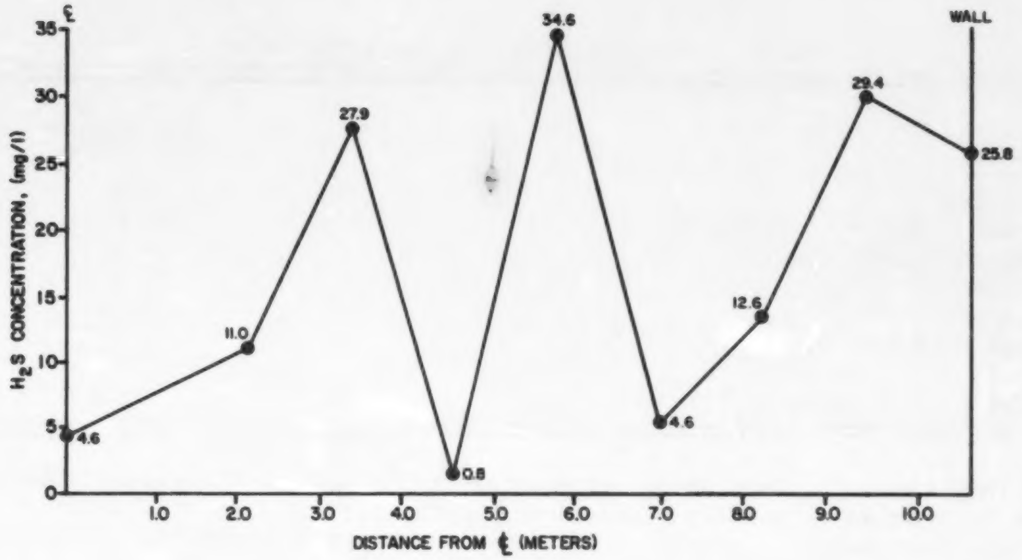


Figure 22. Profile of H_2S Concentrations in Final Clarifier Bottom Sludge

attached to the rotating arms are used to channel the sludge into the withdrawal tubes. The tank center hopper is used only for draining the clarifier. The other plants observed utilize mechanisms which, in addition to channeling sludge to the withdrawal tubes, also scrape bottom sludge to the tank hopper, which is used for waste sludge withdrawal. Waste sludge removal at the special study plant is accomplished through the return sludge system.

It is significant that the bottom sludge which is not removed by the withdrawal tubes [about a 50 cm (2 inch) layer] stays in the clarifier until the unit is drained. This prolonged detention time promotes septicity in the bottom sludge and leads to the development of high concentrations of hydrogen sulfide. Contact of the return sludge with the high sulfide levels at the clarifier bottom may well provide the stimulation for the growth of the Thiothrix organism in the system.

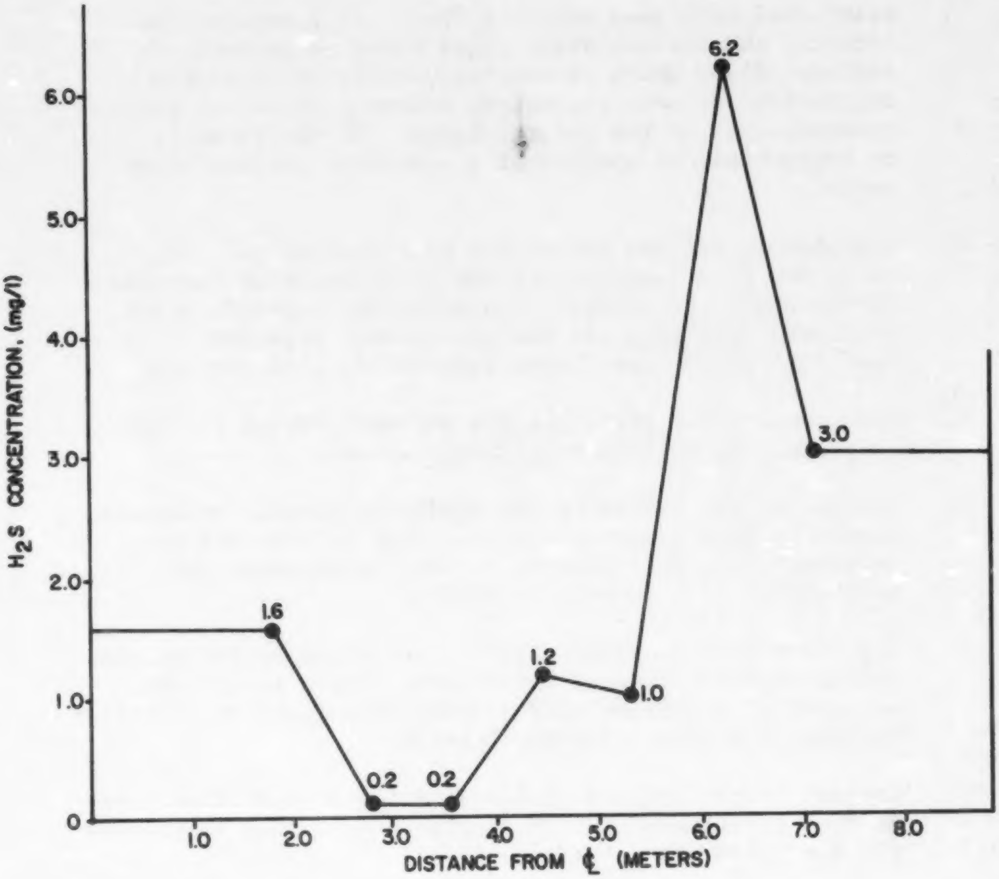


Figure 23. Profile of H_2S Concentrations in Final Clarifier Bottom Sludge

CONCLUSIONS AND RECOMMENDATIONS

The in-depth study of process deficiencies at the special study treatment plant led to the following conclusions:

1. Inadequate final settling inhibits secondary sedimentation and in turn limits process control of the activated sludge system at the plant. Sludge age, F/M ratio, and other parameters cannot be controlled, because sludge return and wasting rates are adjusted to keep the sludge blanket down in the clarifier, rather than to achieve optimum operation in the activated sludge system.

2. Due to the proliferation of filamentous bacteria, solids flux measured in the final clarifiers is well below values

associated with good settling floc. As a result, increasing the recirculation rates above 30 percent of influent flow, which is required to prevent excessive solids release over the weirs, severely thins out the concentration of the return sludge. It was found to be impractical to operate at a desirable recirculation ratio.

3. Microscopic studies showed the hindrance of settling to be due to a large population of filamentous bacteria in the activated sludge. Isolation and identification indicated Thiothrix was the predominant organism. Sphaerotilus in significant numbers are also present.

4. Hydrogen sulfide levels in the influent sewage are not sufficient to stimulate Thiothrix growth.

5. Because of the nature of the sludge withdrawal mechanism, sludge holding times at the clarifier bottoms are excessive. This is conducive to the development and maintenance of high sulfide levels.

6. High levels of hydrogen sulfide were found in the bottom sludge of the secondary clarifiers. These levels are an order of magnitude higher than those found in clarifier bottoms at similar treatment plants.

7. Contact of the settled sludge with the high sulfide level at the clarifier bottoms is probably providing a stimulus for the growth of Thiothrix.

The detailed investigation of process problems in the special study points to one major recommendation. Hydrogen sulfide concentration in the bottom portions of the final clarifiers must be reduced and, if possible, eliminated. Specifically, provisions should be made to scrape the clarifier bottom continuously to insure that all settled material is rapidly removed for waste or recirculation. Since no other significant sources of sulfide exist at the plant, the above clarifier improvements should inhibit the further proliferation of Thiothrix, in that a favorable environment for that organism will no longer exist.

In conjunction with the clarifier improvements and the elimination of the filamentous bacteria, a comprehensive process control program should be initiated. Primary effluent BOD_5, mixed liquor suspended solids, and aeration tank dissolved oxygen should be monitored daily. The information is required to insure that the biological portion of the treatment plant is operated under conditions that favor the growth of a healthy biomass. The tendency for influent organic concentration to fluctuate makes it especially critical that parameters such as F/M ratio and sludge age be monitored and maintained within desirable ranges.

The recommendations proposed are intended to eliminate activated sludge bulking by eliminating the environmental conditions that support the problem organisms. The more traditional approach has been to treat the symptoms of the problem by adding oxidizing agents such as chlorine or hydrogen peroxide to the activated sludge. At best, this method may destroy the filamentous organisms and temporarily ameliorate the settling problem. Experience has shown that the problem will reoccur soon after the oxidant addition is ceased. For this reason, the chemical treatment approach is of limited utility and is not recommended for this facility.

SECTION 8

RELATIONSHIP BETWEEN O&M PARAMETERS AND SIZE AND TYPE OF FACILITY

During the site visit phase of the project, data were obtained from 120 treatment facilities. The primary purpose of the site visit phase was to serve as a screening process for the selection of plants for the preliminary evaluation phase. However, because of the number of plants visited, these data are also useful for developing possible relationships between plant operation and maintenance practices, and the sizes and types of facilities examined. In this section, such relationships as they were found to exist will be examined.

GENERAL INFORMATION

Relative Number of Plants with Respect to Design Capacity (Figure 24)

A significant percentage (38%) of the plants visited were designed for an average daily flow less than 1,890 m^3/d (0.5 mgd). Furthermore, less than one-half of the facilities (45%) exceeded 3,780 m^3/d (1.0 mgd) in design capacity.

Relative Number of Plants with Respect to Facility Type (Figure 25)

Most of the currently employed biological processes were represented in those plants to which site visits were made. About 65 percent of the plants utilized a form of suspended growth process, including activated sludge in the various operating modes. The remaining 35 percent were fixed-film systems including one rotating bio-disc plant.

Relationship Between Service Population and Type and Size of Facility (Table 8)

Treatment processes serving small populations tended to be extended aeration, contact-stabilization, or trickling filter, with extended aeration confined to populations of less than 10,000 for the most part. Larger populations tended to be served by activated sludge plants, particularly by the conventional or complete mix mode.

Relationship Between Type of Wastewater Collection System and Type and Size of Facility (Table 9)

Smaller plants had the highest percentage of separate sewer systems. Treatment method employed showed no correlation with the type of sewer system.

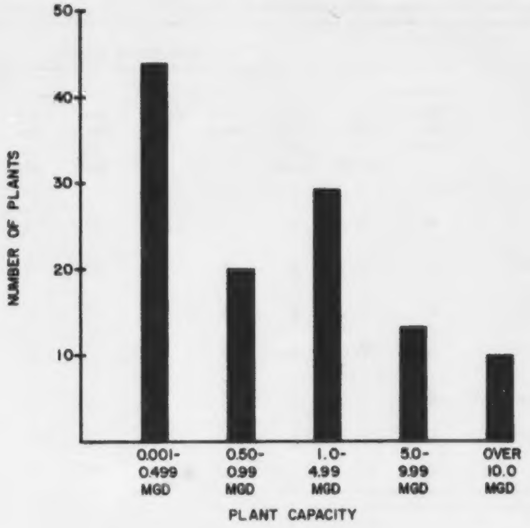


Figure 24. Relative Number of Plants with Respect to Design Capacity

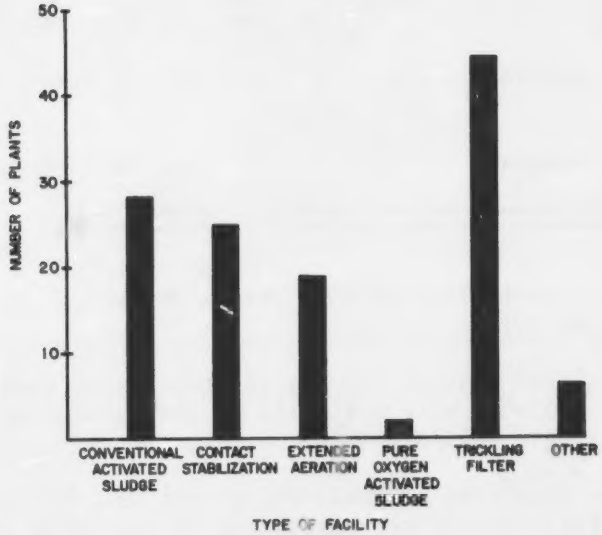


Figure 25. Relative Number of Plants with Respect to Facility Type

TABLE 8. RELATIONSHIP BETWEEN SERVICE POPULATION AND TYPE AND SIZE OF FACILITY

	NUMBER OF PLANTS									
	TYPE OF FACILITY					SIZE OF FACILITY				
	CONV. ACT. SLUDGE	EXT. AER. ACT. SLUDGE	CONT-STAB ACT. SLUDGE	TRICK. FILTER	OTHER	LESS THAN 0.5 MGD	0.5 TO 1.0 MGD	1.0 TO 5.0 MGD	5.0 TO 10.0 MGD	GREATER THAN 10.0 MGD
500-2,500	5	8	8	4	0	17	4	0	0	0
2,500-5,000	0	3	6	11	1	12	9	0	0	0
5,000-10,000	6	2	2	6	0	1	3	10	0	0
10,000-20,000	2	0	0	8	1	0	1	9	0	0
20,000-50,000	6	1	1	5	1	0	0	4	8	1
OVER 50,000	4	0	3	1	1	0	0	0	0	8

TABLE 9. RELATIONSHIP BETWEEN TYPE OF WASTEWATER COLLECTION SYSTEM AND TYPE AND SIZE OF FACILITY

	NUMBER OF PLANTS									
	TYPE OF FACILITY					SIZE OF FACILITY				
	CONV. ACT. SLUDGE	EXT. AER. ACT. SLUDGE	CONT-STAB ACT. SLUDGE	TRICK. FILTER	OTHER	LESS THAN 0.5 MGD	0.5 TO 1.0 MGD	1.0 TO 5.0 MGD	5.0 TO 10.0 MGD	GREATER THAN 10.0 MGD
SEPARATE	12	18	15	29	5	36	14	18	6	5
COMBINED	7	1	6	9	0	3	3	10	4	3

Relationship Between Year of Most Recent Upgrading and Type and Size of Facility (Table 10)

The tabulated results support the hypothesis that most upgradings and new construction projects were motivated by the passage of water pollution legislation in the late 1950's and the 1960's.

With the exception of those few plants greater than 37,850 m^3/d (10 mgd) design capacity, the highest percentage of upgrading occurred in the smallest facilities, indicating either the construction of totally new plants or upgrading to secondary treatment levels. The fact that all the facilities having capacities greater than 37,850 m^3/d (10 mgd) were upgraded since 1970 reflects either the recent trend toward regionalization or the longer time span necessary to plan, design, and construct larger facilities.

TABLE 10. RELATIONSHIP BETWEEN YEAR OF MOST RECENT UPGRADING AND TYPE AND SIZE OF FACILITY

	NUMBER OF PLANTS									
	TYPE OF FACILITY					SIZE OF FACILITY				
	CONV. ACT. SLUDGE	EXT. AER. ACT. SLUDGE	CONT-STAB ACT. SLUDGE	TRICK. FILTER	OTHER	LESS THAN 0.5 MGD	0.5 TO 1.0 MGD	1.0 TO 5.0 MGD	5.0 TO 10.0 MGD	GREATER THAN 10.0 MGD
BEFORE 1940	1	0	0	0	0	0	0	0	1	0
1940 TO 1950	0	0	0	1	0	0	0	1	0	0
1950 TO 1960	1	1	0	7	0	3	1	3	2	0
1960 TO 1970	8	11	6	19	1	19	11	9	6	0
SINCE 1970	10	3	10	7	3	10	5	8	1	9

Relationship Between Wastewater Characteristics and Type and Size of Facility (Table 11)

Industrial wastewaters appear to be distributed among all process types, except extended aeration facilities. The small size and limited service area of most extended aeration plants probably explain the absence of significant industrial wastewater volumes. Their service areas are generally not industrial, and, therefore, smaller plants have the higher percentage of domestic wastewaters. Conversely, the plants with capacities greater than 37,850 m^3/d (10 mgd) exhibited the greatest percentage of high industrial loadings.

TABLE 11. RELATIONSHIP BETWEEN WASTEWATER CHARACTERISTICS AND TYPE AND SIZE OF FACILITY

	NUMBER OF PLANTS									
	TYPE OF FACILITY					SIZE OF FACILITY				
	CONV. ACT. SLUDGE	EXT. AER. ACT. SLUDGE	CONT-STAB ACT. SLUDGE	TRICK. FILTER	OTHER	LESS THAN 0.5 MGD	0.5 TO 1.0 MGD	1.0 TO 5.0 MGD	5.0 TO 10.0 MGD	GREATER THAN 10.0 MGD
DOMESTIC	12	16	13	21	5	32	14	15	2	4
LOW INDUSTRIAL < 10%	2	0	1	6	1	3	1	3	2	1
MODERATE INDUSTRIAL (10-20%)	1	0	5	6	0	3	2	2	3	2
HIGH INDUSTRIAL (20-50%)	6	1	3	4	2	1	3	8	2	2

Relationship Between Industrial Waste Impact and Type and Size of Facility (Table 12)

The impact of industrial wastewaters on the treatment facility did not appear to vary with respect to the size or type of plant. This indicates that while larger plants have the higher industrial loadings, they are also more able to handle industrial wastes without experiencing process problems.

TABLE 12. RELATIONSHIP BETWEEN INDUSTRIAL WASTE IMPACT AND TYPE AND SIZE OF FACILITY

	NUMBER OF PLANTS									
	TYPE OF FACILITY					SIZE OF FACILITY				
	CONV. ACT. SLUDGE	EXT. AER. ACT. SLUDGE	CONT-STAB ACT. SLUDGE	TRICK. FILTER	OTHER	LESS THAN 0.5 MGD	0.5 TO 1.0 MGD	1.0 TO 5.0 MGD	5.0 TO 10.0 MGD	GREATER THAN 10.0 MGD
MINIMAL	17	17	18	26	5	35	16	20	4	8
LOW	2	2	1	3	0	2	2	2	2	0
MODERATE	4	1	4	7	2	3	3	6	4	2
HIGH	1	0	0	0	0	1	0	1	0	0

Relationship Between Infiltration/Inflow Impact and Type and Size of Facility (Table 13)

Infiltration/Inflow (I/I) demonstrated a moderate to severe effect on 43 percent of all plants examined during the site visit phase. The trickling filter plants as a group had the highest amounts of extraneous flows in their collection systems, probably because the plants and their collection systems tended to be older. However, the effect on performance at those plants receiving excessive volumes of I/I was greater at suspended growth facilities for reasons discussed in Section 5. No correlation was seen between size of plant and impact of I/I.

TABLE 13. RELATIONSHIP BETWEEN INFILTRATION/INFLOW IMPACT AND TYPE AND SIZE OF FACILITY

	NUMBER OF PLANTS									
	TYPE OF FACILITY					SIZE OF FACILITY				
	CONV. ACT. SLUDGE	EXT. AER. ACT. SLUDGE	CONT-STAB ACT. SLUDGE	TRICK. FILTER	OTHER	LESS THAN 0.5 MGD	0.5 TO 1.0 MGD	1.0 TO 5.0 MGD	5.0 TO 10.0 MGD	GREATER THAN 10.0 MGD
MINIMAL	4	5	6	9	1	9	4	8	3	1
LOW	10	4	5	10	5	9	8	9	3	5
MODERATE	5	6	8	20	0	16	7	9	5	2
HIGH	0	0	1	0	0	1	0	0	0	0

OPERATION

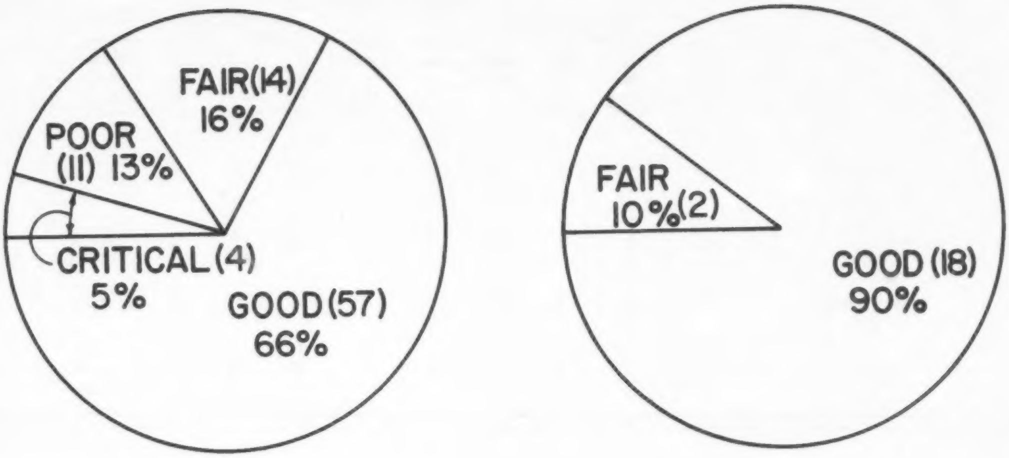
Each plant was rated on a scale of 0 - 3 as to its standing in various operational categories. The best standing (0) is defined as good, next is fair (1), then poor (2), and, finally, critical (3). The following figures show the plant rating distribution for each category. The numbers in parentheses are the actual numbers of plants so rated.

Relationship Between Staff Capabilities for Operation and Size and Type of Facility (Figure 26)

As previously noted, the term "staff capabilities" represents four characteristics of the plant staff, (1) staff size, (2) training, (3) certification, and (4) treatment understanding. For the most part, large plants were capable of maintaining an adequately sized staff because of more flexibility in budgetary matters. Similarly, large facilities were better equipped to administer in-plant training programs and sufficiently flexible to accommodate personnel attending training and certification classes. Generally, the trickling filter processes scored better than the activated sludge plants because operation of the trickling filter facility is usually less demanding in terms of operational requirements and process knowledge. Greater training and treatment understanding are required to control the more complex activated sludge process

Relationship Between Use of Laboratory and Size and Type of Facility (Figure 27)

Larger plants made significantly greater use of the laboratory than did the smaller facilities. Because of the larger staff sizes, a greater percentage of labor, and more specialized workers, could be devoted to laboratory-related work. Regarding type of process, use of the laboratory appears to be more effective at trickling filter plants, most likely as a result of fewer



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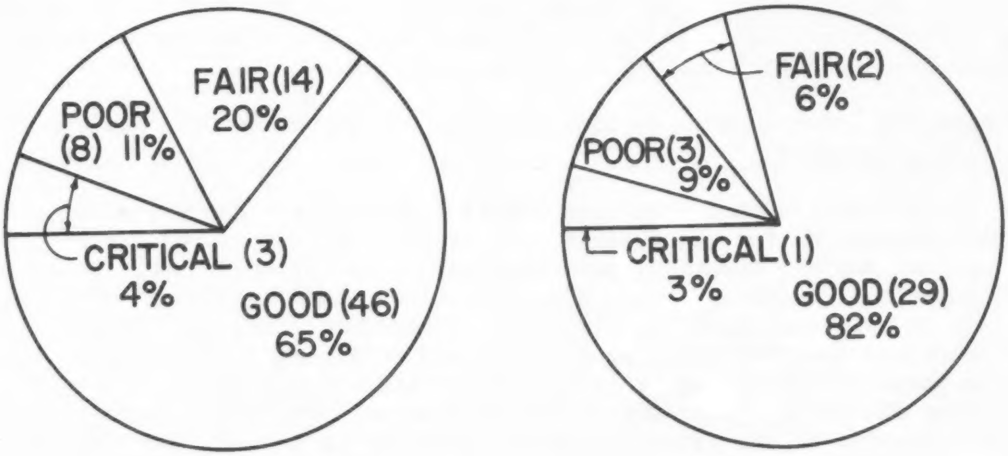

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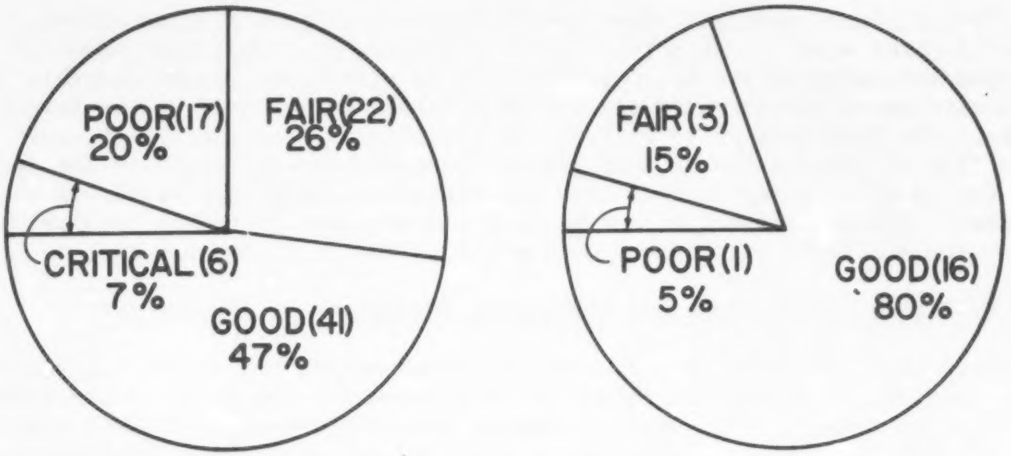
Figure 26. Relationship Between Staff Capabilities for Operation and Size and Type of Facility



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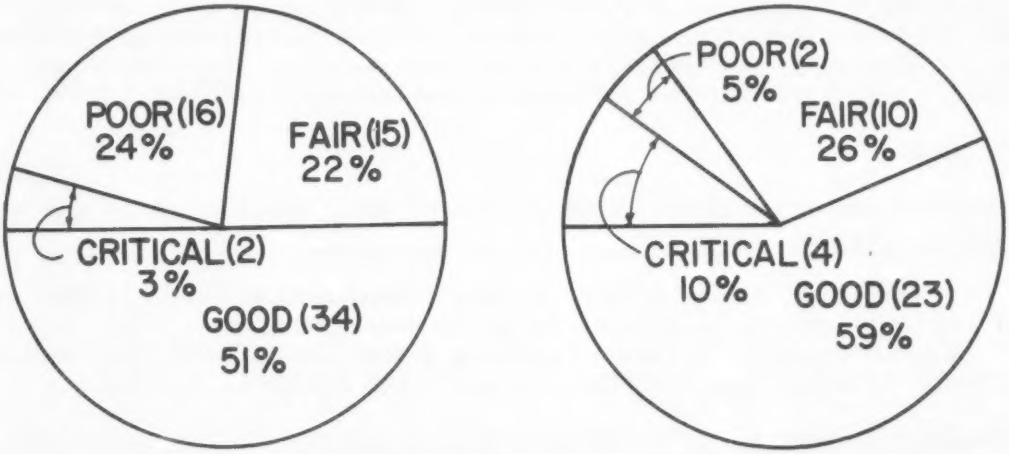


(ACTIVATED SLUDGE)   (TRICKLING FILTER)

Figure 27. Relationship Between Use of Laboratory and Size and Type of Facility

process variables to monitor.

Relationship Between Process Control and Size and Type of Facility (Figure 28)

Larger plants exercised greater process control than smaller plants. Adequately sized staffs, suitably trained laboratory personnel, and properly equipped laboratories are all prerequisites to effective process control. As previously noted these conditions are more likely to be found at the larger plants. The fact that 83 percent of the trickling filter facilities were rated fair or good in the area of process control actually reflects the fact that few control options (other than recirculation ratio) are available to the operator. Process control at a trickling filter plant, therefore, requires a lower level of effort than is required for the activated sludge process.

Quality Evaluation of Technical References for Operation (Figure 29)

Less than one-third of the plants examined during the site visit phase were judged to have adequate technical references for operation of the facility. For purposes of this study, adequate references would include a comprehensive operations manual, information provided by the equipment manufacturers, and as-built drawings of the facilities.

Evaluation of Use of Consulting Engineering Services (Figure 30)

Based on the opinions of the operators, consulting services were utilized adequately in a majority of cases. However, this assessment may be optimistic, since the operators frequently felt little assistance of this nature was necessary, even where serious performance problems have been documented.

MAINTENANCE

Relationship Between Staffing Capabilities for Maintenance and Size and Type of Facility (Figure 31)

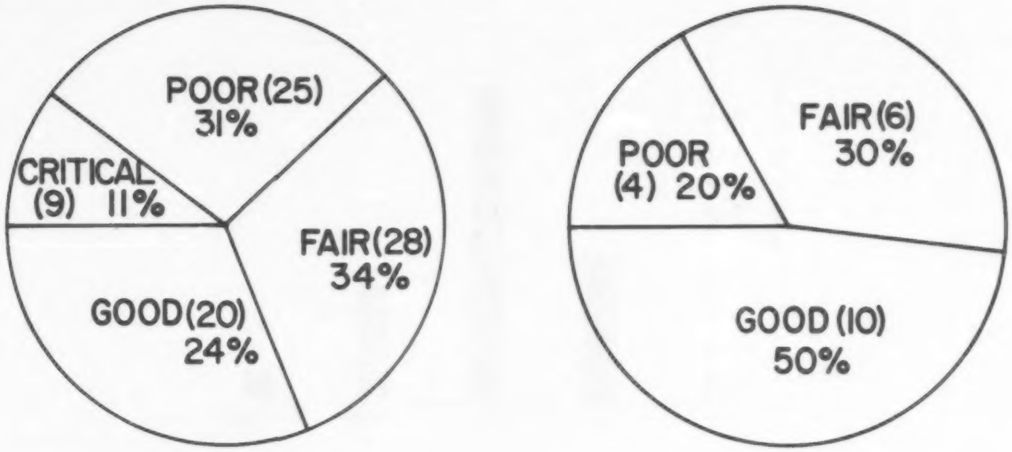
As experienced, larger plants had more adequate maintenance staffs, since staff size was found to be a major factor in determining maintenance capabilities for a given plant size. Trickling filter plant staffs were more maintenance oriented than were those at activated sludge facilities.

Relationship Between Age of Equipment and Size and Type of Facility (Figure 32)

No correlation was found between size of plant and age of equipment. The fact that treatment plant designs have trended toward activated sludge and away from trickling filters in recent years is demonstrated by the higher proportion of newer equipment in activated sludge facilities.

Relationship Between Spare Parts Inventory and Size and Type of Facility (Figure 33)

Larger plants maintained a more complete inventory of spare parts. This was probably due to better organization and greater administrative attention given to larger facilities. However, the adequacy of such inventories was not



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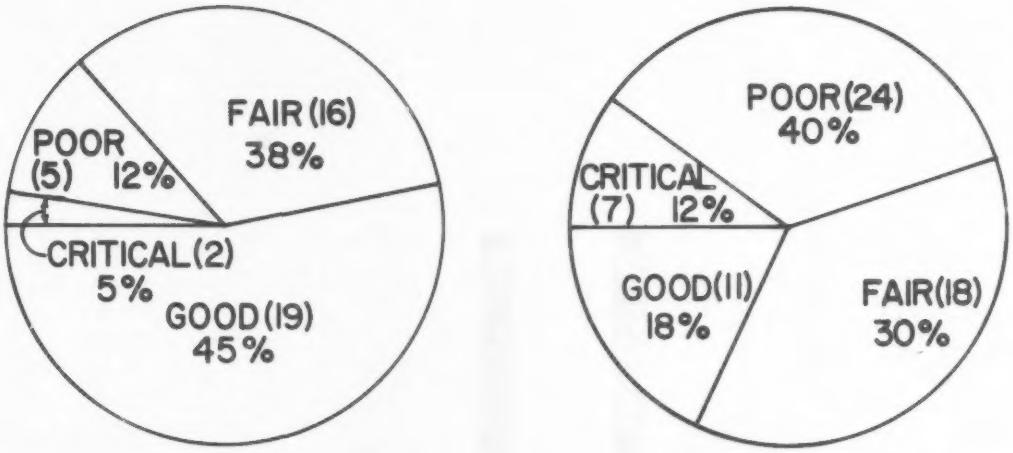


(TRICKLING FILTER) (ACTIVATED SLUDGE)

Figure 28. Relationship Between Process Control and Size and Type of Facility

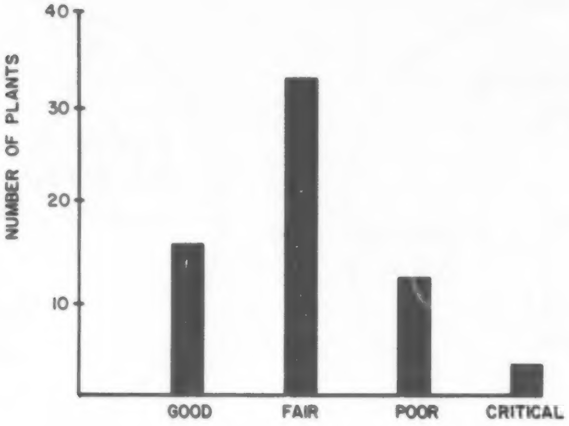


Figure 29. Quality Evaluation of Technical References for Operation

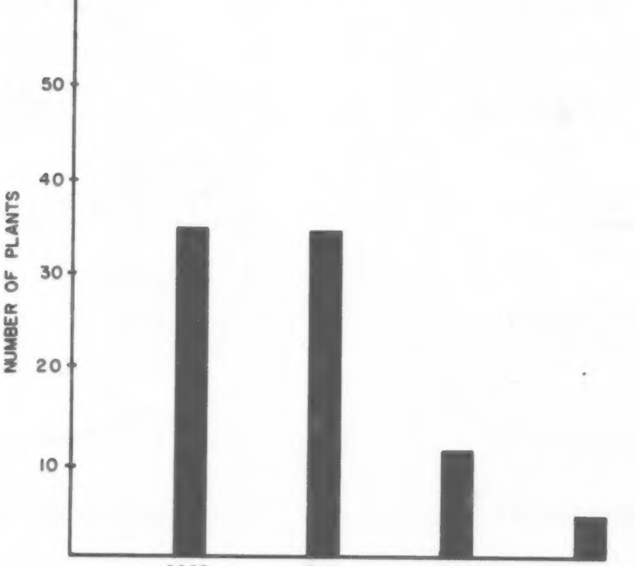
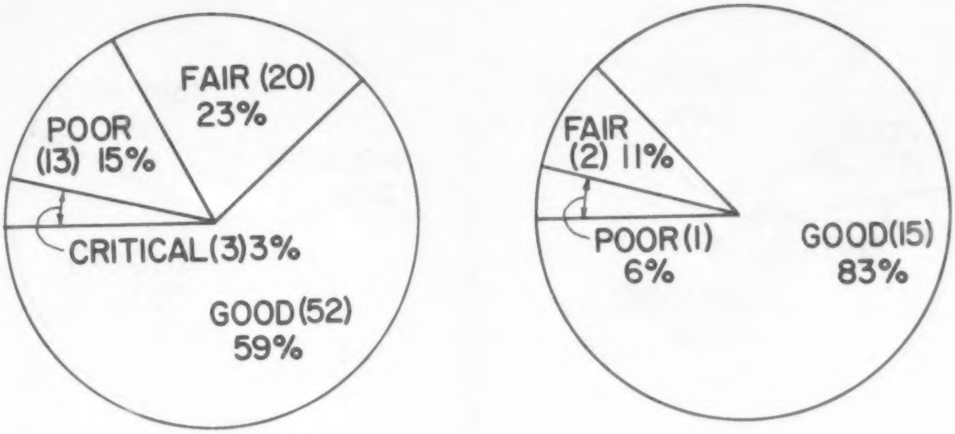


Figure 30. Evaluation of Use of Consulting Engineering Services



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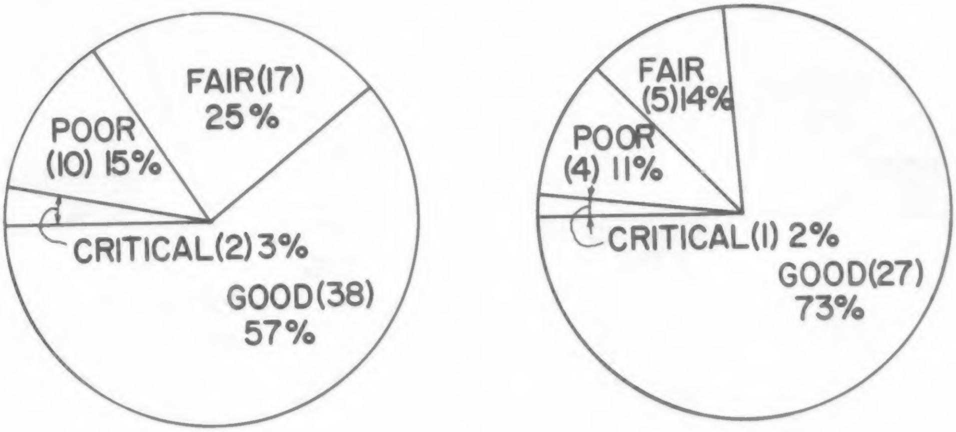

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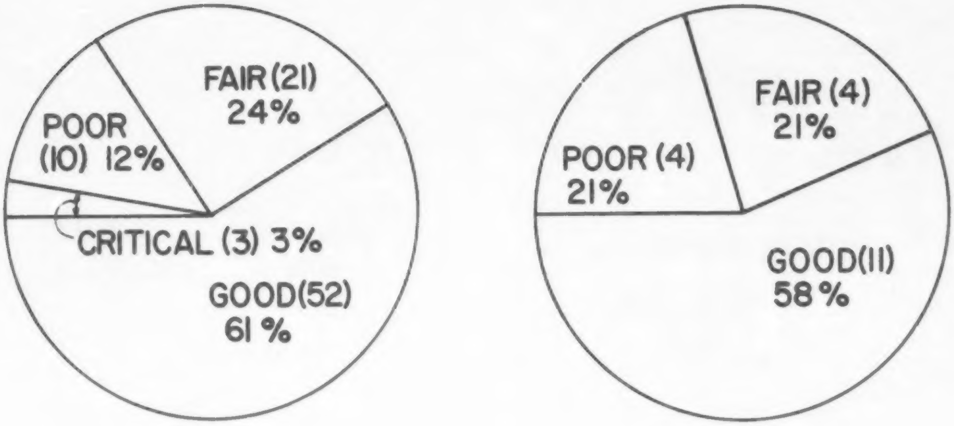
Figure 31. Relationship Between Staffing Capabilities for Maintenance and Size and Type of Facility



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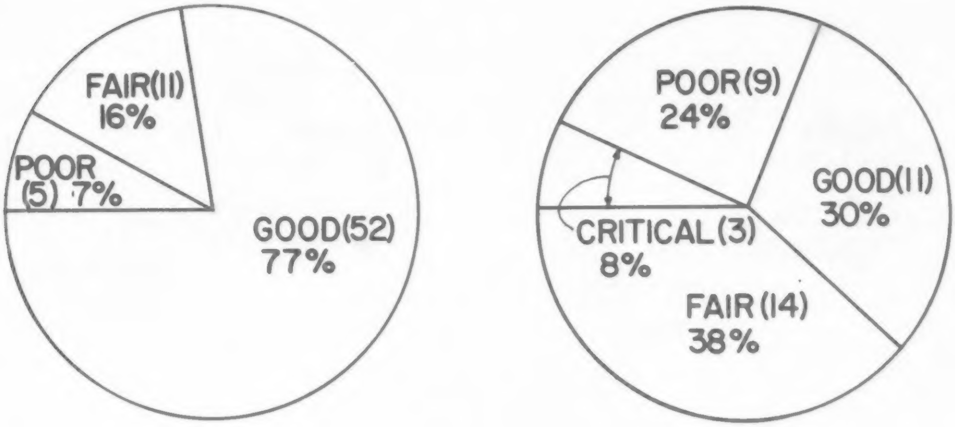

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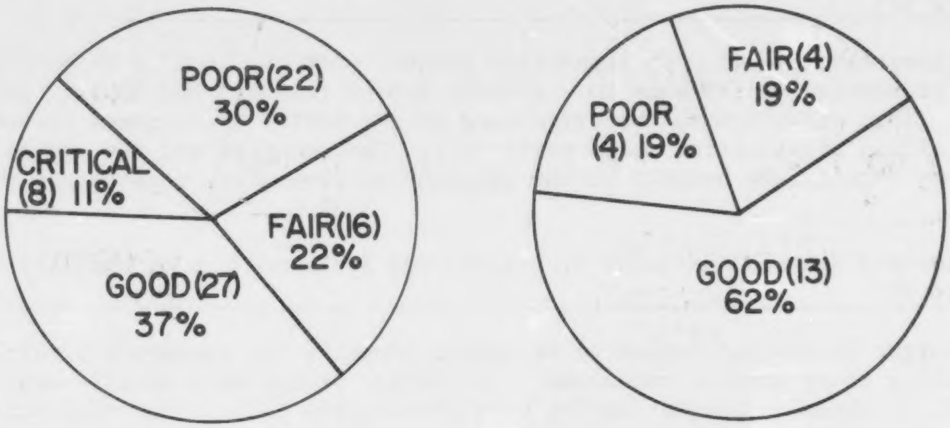
Figure 32. Relationship Between Age of Equipment and Size and Type of Facility



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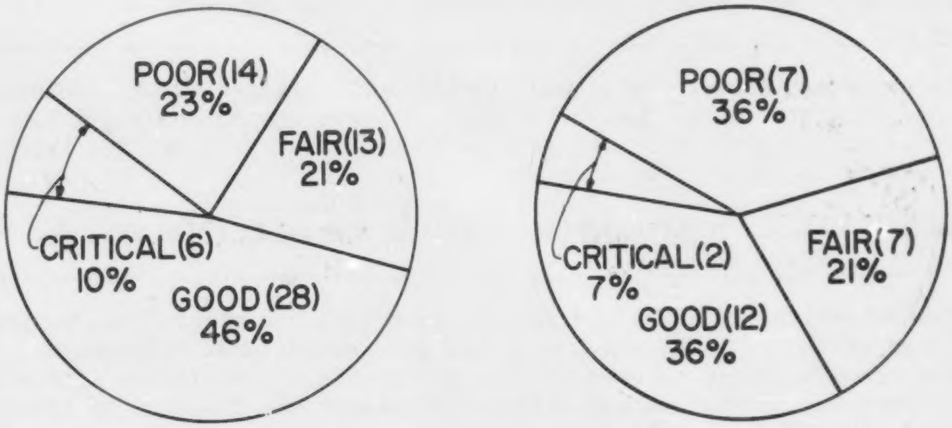


(ACTIVATED SLUDGE) (TRICKLING FILTER)

Figure 33. Relationship Between Spare Parts Inventory and Size and Type of Facility

related to process type.

Relationship Between Preventive Maintenance and Size and Type of Facility (Figure 34)

Generally, plants with capacities greater than 18,920 m^3/d (5 mgd) practiced preventive maintenance to a greater extent than did the smaller facilities. This condition can be attributed to the better spare parts inventories and staffing capabilities noted previously. Process type did not appear to have any significant bearing on the adequacy of preventive maintenance practices.

Relationship Between Emergency Provisions and Size and Type of Facility (Figure 35)

Larger facilities tended to be better prepared for emergency situations, reflecting their greater resources. The larger plants were usually new, enlarged, or upgraded plants having been constructed in a period when some emergency provisions, such as emergency power supply and duplicate units, became mandatory for design approval. The extent to which facilities were prepared for emergencies did not appear to be related to process type.

Relationship Between Backup Unit Provisions and Size and Type of Facility (Figure 36)

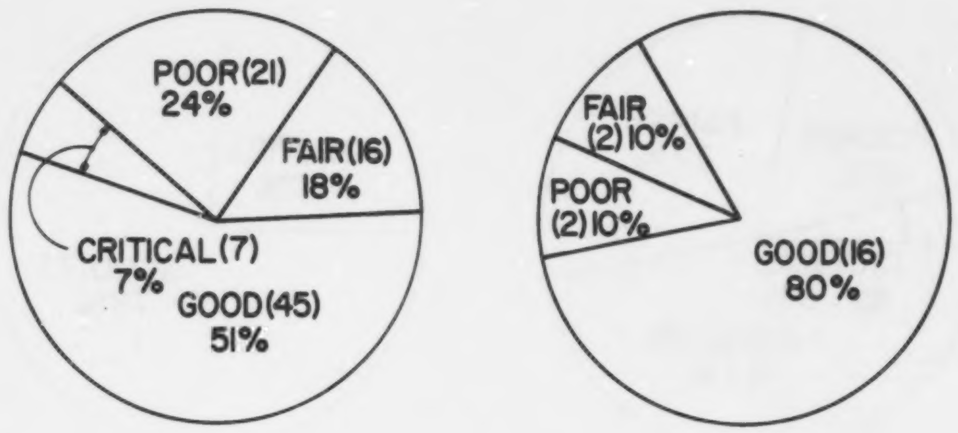
As expected, larger plants had significantly greater backup capability since all such plants had dual or multiple process units. No significant difference in backup provisions was seen between activated sludge and trickling filter plants in the site visit phase.

Relationship Between Technical References for Maintenance and Size and Type of Facility (Figure 37)

Comprehensive, organized technical references for maintenance purposes were found at those plants which also had good operational references. The adequacy of maintenance references showed a positive correlation with plant size. There was no significant difference between the fraction of trickling filter plants and activated sludge plants having adequate maintenance references. The extent to which such references are required for trickling filter plants would be less, again due to the lesser amount of mechanical equipment involved.

Relationship Between Housekeeping Practices and Size and Type of Facility (Figure 38)

Housekeeping practiced at larger wastewater treatment facilities was found to be slightly more satisfactory than that practiced at smaller plants. This was undoubtedly a result of a combination of factors related to plant size, including availability of maintenance staff, age of equipment, and administrative practices. No appreciable difference in quality of housekeeping was observed between trickling filter and activated sludge processes.



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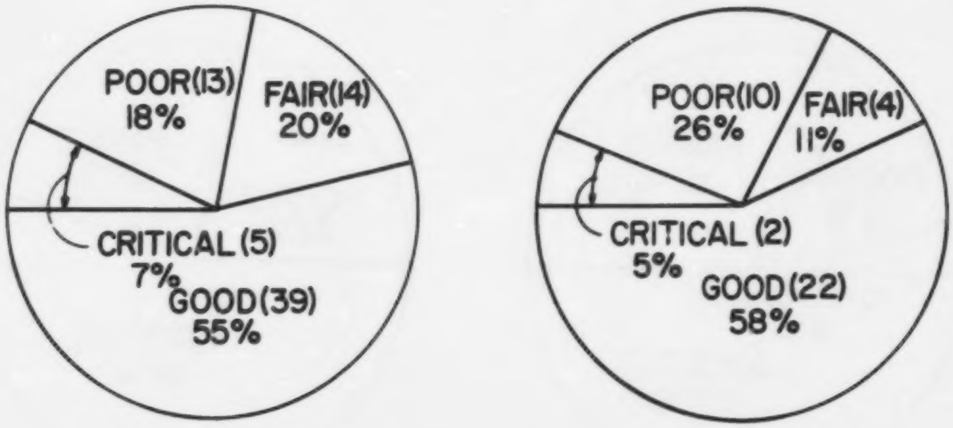

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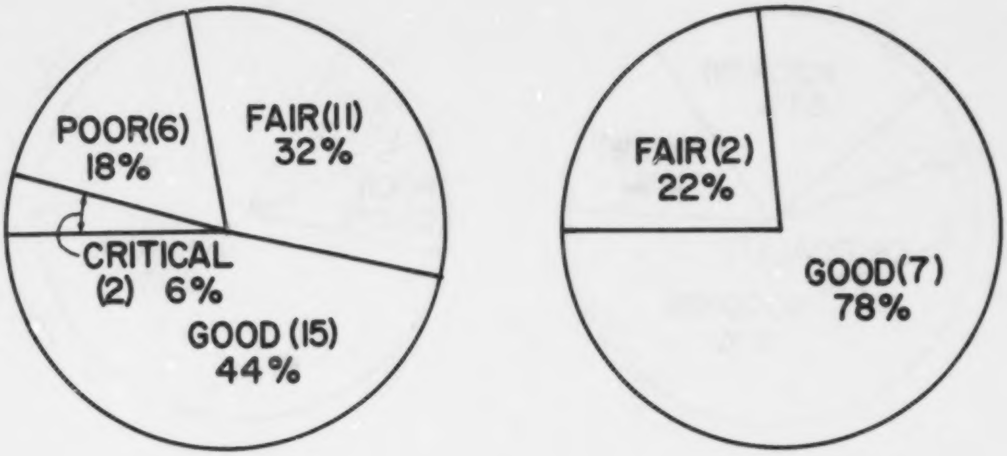
Figure 34. Relationship Between Preventive Maintenance and Size and Type of Facility



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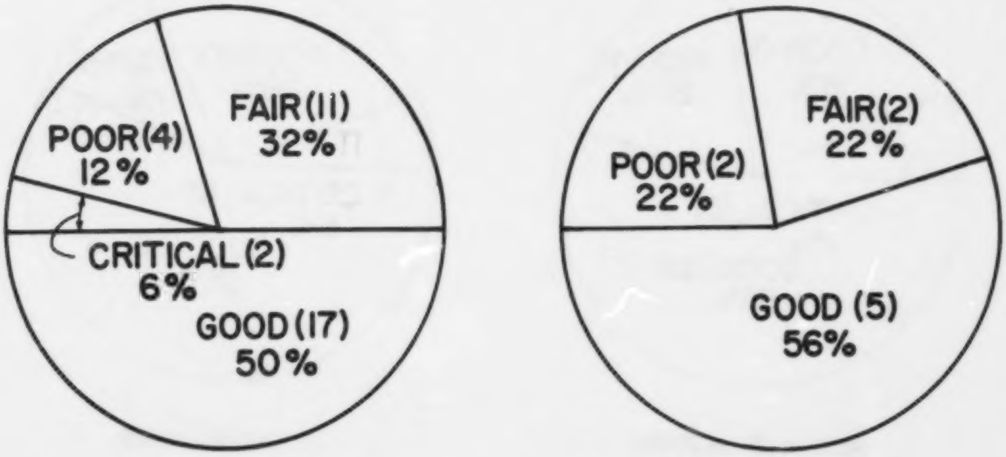

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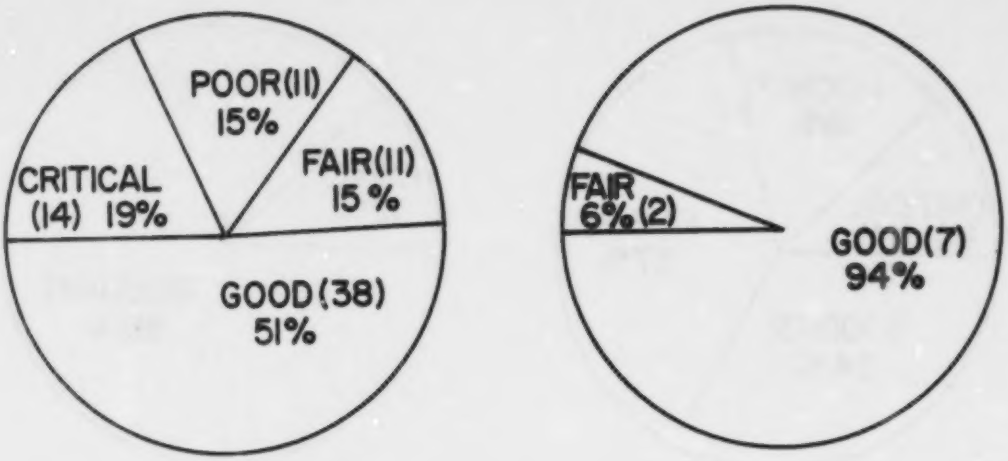
Figure 35. Relationship Between Emergency Provisions and Size and Type of Facility



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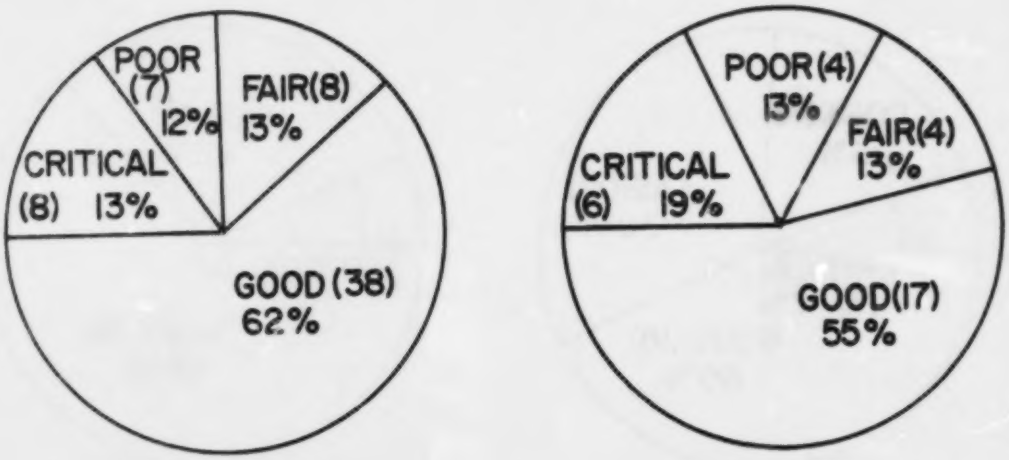

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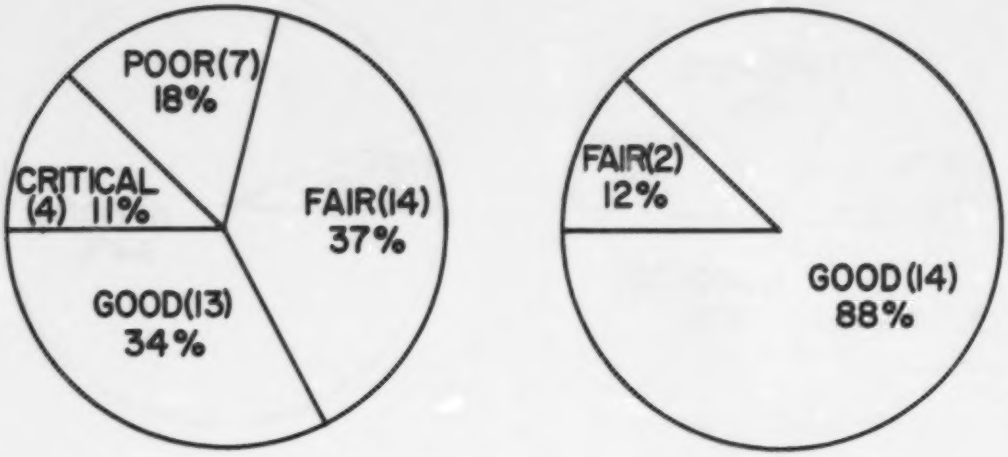
Figure 36. Relationship Between Backup Unit Provisions and Size and Type of Facility



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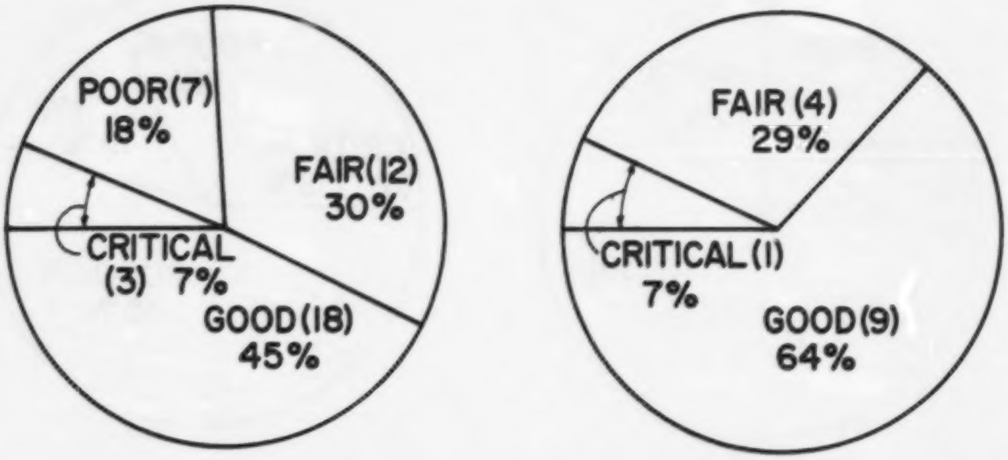

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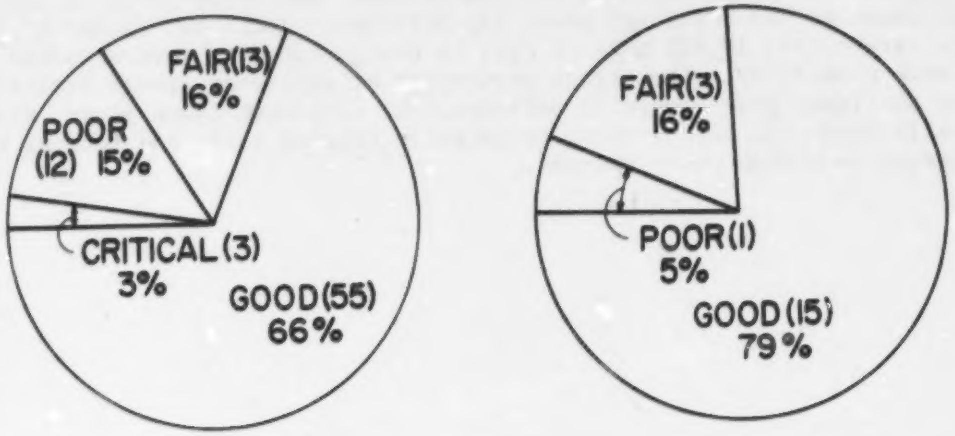
Figure 37. Relationship Between Technical References for Maintenance and Size and Type of Facility



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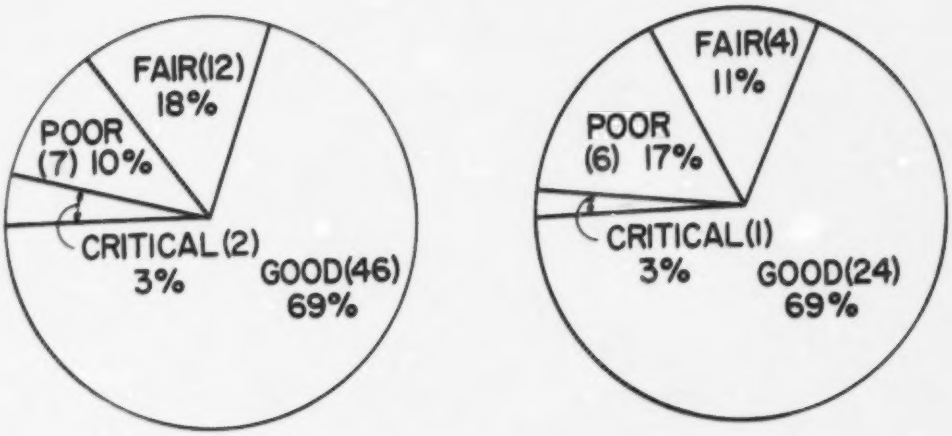

(ACTIVATED SLUDGE) (TRICKLING FILTER)

Figure 38. Relationship Between Housekeeping Practices and Size and Type of Facility

Relationship Between Availability of Auxiliary Power and Size and Type of Facility (Figure 39)

Approximately one-third of the plants less than 18,920 m^3/d (5 mgd) in design capacity had auxiliary power capabilities. About two-thirds of those plants larger than 18,920 m^3/d (5 mgd) in design capacity were reported to have such capability. The higher percentage of activated sludge facilities having auxiliary power capacity reflected the fact that these plants were generally newer and were subject to recently enacted state and federal requirements on backup power systems.

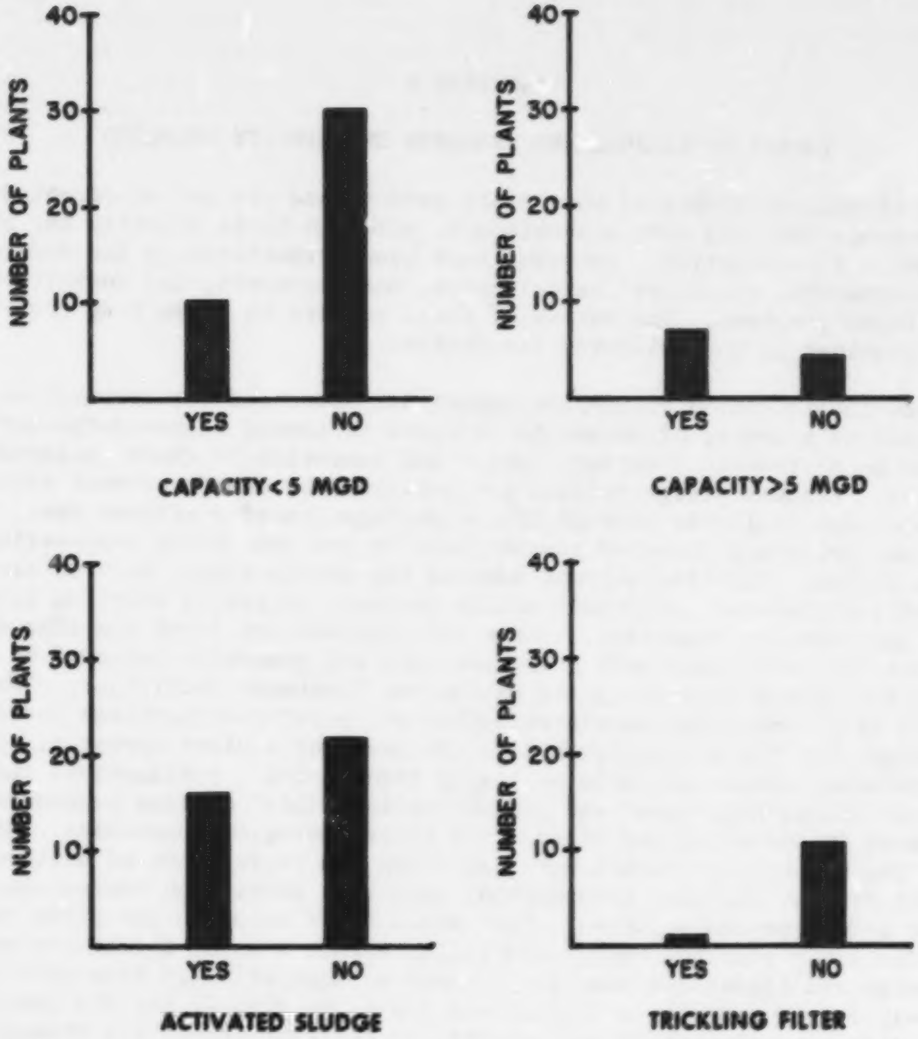

Figure 39. Relationship Between Availability of Auxiliary Power and Size and Type of Facility

SECTION 9

IMPACT OF ESTABLISHED PROGRAMS ON PRIORITY PROBLEMS

The causative factors of poor plant performance are not of recent origin. Their presence has long been acknowledged, although their priority has been more difficult to identify. Programs have been established by the federal and state governments, operators' associations, manufacturers, and consultants to resolve these problems. The extent of those efforts in correcting these problems is examined in the following discussion.

Since the inception of EPA, the Agency has sponsored the preparation and publication of a number of documents designed to convey state-of-the-art information on wastewater treatment design and operation to those employed in this field. Process design manuals are published by the Government Printing Office and made available through EPA Technology Transfer without fee. These manuals are primarily directed toward those in the consulting engineering and academic fields. Existing volumes address key design areas, such as sludge treatment and disposal, suspended solids removal, upgrading existing treatment plants, and tertiary treatment. These publications set forth specific design parameters for individual unit processes, and are generally intended as a guide to the preliminary design of wastewater treatment facilities. These documents will contribute to the reduction of operational problems associated with design, but few are applicable to the needs of a plant operator. Operations-related manuals are also available through EPA. Publications such as "Anaerobic Sludge Digestion" and "Stabilization Ponds" outline procedures to be followed in operating and controlling these biological processes. Similarly, the "Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants" includes information, such as a section on common operating problems and suggested solutions, that would be of value to the plant operator. The study reported here would indicate that a major difficulty with both design and operations manuals is their dissemination to treatment plants. Relatively few of the plants visited had copies on file of any EPA publications. Although this effort may benefit the operator indirectly through his consultant, the information is not reaching the operator directly where it would be of greatest benefit.

Under the construction grants program established as a result of the Water Pollution Control Act Amendments of 1972, federal funds are available to municipalities seeking to reduce infiltration/inflow. In the design of new facilities involving federal funds, a cost-effectiveness analysis must be performed during the facilities planning step of the project. On the basis of this study a sewer rehabilitation program may be implemented to reduce infiltration/inflow to the cost-effective level. As new plants are constructed, the I/I problem will diminish, but as sewer systems continue to age and deteriorate, new critical cases will develop. The federal program will help to reduce the overall magnitude of the adverse effects of I/I on sewage treatment plant performance when one looks at the overall national picture. However, looking at specific cases, only those plants which become involved in upgrading or expansion will be encouraged to address their I/I situation. Therefore, many plants currently experiencing operational difficulties resulting from excessive I/I will not be affected by existing federal programs.

Established programs to date have had little impact on the industrial loadings to municipal treatment plants. Local programs have consisted of provisions in municipal ordinances setting forth surcharges for discharge of high concentration of certain pollutants to the collection system, and placing limitations or bans on discharge of other pollutants. However, such ordinance provisions have, in the past, been very poorly enforced for two reasons:

1. Time and manpower are not available to vigorously monitor industrial wastes.

2. Rigorous enforcement may have caused conflicts with major employers in the community.

Two recent programs should result in amelioration of some industrial loading problems. First, the ICR-User Charge provisions of PL 92-500 have caused, and will continue to cause, industries to consider the economics of pretreating their wastewaters. Sewer rental rates to industry under ICR-User Charge regulations are directly proportional to wastewater flow and characteristics. Such rental rates can often be substantially reduced by treating to reduce pollutant concentrations. Of broader and more direct significance, however, are the recently promulgated (June 26, 1978) industrial pretreatment regulations. These general regulations identify 21 industrial categories for which specific pretreatment guidelines will be established within the next three years. Also, limits will be established for 65 toxic pollutants which all dischargers to municipal treatment plants will be required to meet. Administration of the pretreatment program will be the responsibility of the municipality where the design flow of the plant is greater than 18,920 m^3/d (5 mgd). In all other cases, the state agency or EPA will be required to accept this responsibility. As the pretreatment limits are set forth for each industry, the incompatible pollutants and slug loadings currently reaching municipal treatment plants will diminish. Of course, this prediction assumes adequate administration of the program and compliance by industry.

As a requirement of the construction grants program, O&M manuals are now being prepared for all federally funded wastewater collection and treatment systems. The purpose of this requirement is to insure that all federally funded treatment facilities being constructed have comprehensive plant-specific manuals. Through adherence to the EPA document, "Consideration for Preparation of Operation and Maintenance Manuals," and as a result of detailed review by EPA, these manuals should conform to EPA standards. As existing plants are upgraded and new ones built, the problem of O&M manual inadequacy should greatly diminish. Also, many consulting firms are now involving the plant operator in the preparation of the O&M manual, and are using the manual as a training device. This will result in a manual that is more responsive to the operators' needs, and use of the document should increase.

All states now operate a mandatory or voluntary program of operator certification. Though all state programs have been developed and are administered independently, they have had the effect of assuring some minimum competence level for certified operators, based on the size and complexity of the treatment plant. In the program's early years, certification was an effective means of increasing the training level of operators. Currently, most plants meet the requirements for certified operators, and enough additional operators are being certified to meet the needs of newly-constructed facilities. Certification programs have their place in assuring minimum competency; however, in their present form, they do not insure that learned principles and techniques will be applied in on-site operational situations.

Training programs play a major part in providing basic wastewater treatment knowledge to potential and practicing treatment plant operators. Examples of such programs include the Sacramento course and Clemson course, and other courses sponsored by the state agencies, water pollution control organizations, technical schools, and community colleges.

In Pennsylvania, the Sacramento course is offered through the Department of Community Affairs. Operator training provides basic understanding of treatment principles and fundamentals, training in laboratory procedures, and exposure to process control technology. Originally, these courses were designed to enable a plant operator to learn the material necessary to become certified. A basic shortcoming of these courses is that they are designed for an individual with little or no wastewater background, and, hence, are limited in what they offer to an experienced individual who seeks to upgrade his skills. A few community colleges offer advanced courses or an associate degree program, which are designed for experienced personnel interested in supervision of operation and maintenance personnel. Enrollment in these programs requires time and money, which makes them inaccessible to many operators. The courses available to a majority of operators do not provide sufficient exposure to convey the depth of understanding necessary for meaningful process control application or testing. The findings of this study would indicate that classroom training must be supplemented with on-site training to more effectively convey process control concepts to the operator.

Equipment manufacturers typically provide excellent material on the maintenance and operation of their products, particularly for equipment that is standard or for which operating experience is available. For new products or processes, less information is available, especially in the area of operations. The quality of assistance in the form of trained personnel available varies among manufacturers and among individuals representing each manufacturer. Manufacturers' representatives are a potentially excellent source of knowledge, if suitable contractural arrangements can be made for their services. For small package plants, operators may possibly have access to the manufacturer who could provide operating assistance. For large treatment systems, assistance with the biological process operation is not likely to come from an equipment manufacturer. However, manufacturers of proprietary unit processes, such as pure oxygen activated sludge, can usually provide operating assistance. In general, the manufacturer must be considered a specialized temporary source of technical assistance to the operator.

Some consulting firms maintain a qualified staff to provide technical and administrative assistance to municipal wastewater clients. Such a staff typically includes personnel who are certified treatment plant operators with a thorough knowledge of process theory or design concepts. An engineer without first-hand operating experience is rarely as successful in providing operational assistance as an experienced operator. Plants evaluated in this study reported a low level of consultant service. Those having consultants available usually did not use them for training or problem-solving. Those not retaining consultants felt that consultant services would not be beneficial. Personnel at most plants seemed to feel that an engineer could not help with operating problems. Most consulting firms at this time do not maintain the type of staff necessary to offer technical assistance at the operating level, nor do they indicate to their clients that such services are available elsewhere. This area of service is growing, however, and will be offered by an increasing number of engineering firms in the future.

Within the wastewater industry, associations have existed for a number of years to foster professionalism, increase the technical knowledge of their members, and to effectively represent the members' interest and opinions. Some associations, such as the Water Pollution Control Federation, have developed or sponsored operator training courses. Additionally, they sponsor seminars and workshops, and issue publications aimed at improving the knowledge of plant operators. Such organizations provide the opportunity for operators to discuss problems with their colleagues and occasionally find solutions. Overall, the associations provide some valuable training, but they have a small to moderate effect on reducing the magnitude of problems associated with process control and understanding.

The problems of application of concepts, lack of adequate testing, inadequate training, and deficient understanding will not be fully resolved by any of the established programs discussed above. To date, the programs directed at these problems - O&M manual preparation, operator training courses, technology transfer publications, and testing for certification - are too generalized in content while the need is for specific on-site learning experience.

O&M manuals are prepared by the consultant with little or no input from the plant operators. Little opportunity is given the operator to come to an understanding of the manual's contents or to be instructed on how they should be used. Many O&M manuals are ending up on the shelf, unused, for these reasons. The organizational format of many O&M manuals has been criticized to the EPA in earlier comments by many groups. The accuracy of some O&M manuals is also questionable, since they represent information derived during the early design stages of a project and do not accurately reflect actual operation.

Operator training courses of all types - Sacramento, Clemson, correspondence, association-sponsored, seminars, and workshops - do offer excellent opportunities for textbook learning that can improve an operator's understanding of treatment goals and methods. But very few programs bridge the gap between classroom learning and concept application with hands-on experience or site specific, on-the-job training. This same difficulty is present in technology transfer publications, and in certification programs that rely solely on (or include as a criterion) the ability to score satisfactorily on a written exam.

Wastewater treatment plants vary in size and complexity and in the quality of the operating personnel. It can safely be said that, in terms of total number of plants, relatively few are large and complex; the majority are much smaller but may involve some complex processes. Large plants with appropriate budgets can attract qualified superintendents who can insure that lower level personnel are properly trained for their work through both classroom and on-the-job instruction. Smaller plants are less likely to have highly trained superintendents, adequate budgets, and training capabilities, and therefore, are more dependent on training achieved through programs such as certification.

Effective training to produce qualified (not merely certified) operators requires a bridge between the existing training programs and site-specific training assistance in process control and laboratory testing in the plant. A similar bridging mechanism must also provide additional knowledge to personnel at other plants experiencing problems which still may be beyond the capabilities of the staff.

The bridging mechanism suggested is best provided by persons who are knowledgeable and experienced in process theory, hands-on operation of equipment and processes, and training techniques. These persons, working with the plant operators over an extended time period, would be "outside experts" who could both identify and solve problems, and teach the operators process control. In this manner, the operator supplements the knowledge he has gained away from the plant, and is given the opportunity to exercise process control while under the supervision of an experienced individual.

The EPA recognized the viability of such a concept by issuing under the construction grants program its Program Requirements Memorandum (PRM) #77-2 in November 1976. This PRM authorized grant funding for up to 300 man-days (an average of 90 man-days for most plants) of start-up services per plant for the plant's first year of operation, to be rendered by the design engineer or his designees. These covered services, applicable to new, expanded, or upgraded plants include pre and post start-up on-site training, control adjustments to optimize process performance, instruction in laboratory procedures, maintenance and records management, and O&M manual revision. Specifically, nongrant fundable are routine, entry-level, or update operator training.

PRM #77-2 was established to fund start-up services to insure that: "design operational efficiency is achieved as quickly as possible; process control and related equipment problems are identified and resolved; on-site instruction to personnel in details of the process and equipment of each particular plant is provided, and final revisions to the O&M manual, based upon actual operating experience, are made." Plants which have recently upgraded or do not need to construct additional processes to handle their design loadings will not be eligible for this assistance. Yet, as this study has shown, plants in this category may also be experiencing severe problems preventing their achieving permit compliance. The type of service detailed in

PRM #77-2 should be available to all plants requiring assistance in problem-solving regardless of the age of the facility. These services are available to a varying degree from consulting firms, although they are not eligible for federal funding. Making such services eligible for federal funds would increase the likelihood that municipalities would use them. Under the existing statutes, EPA or the states cannot require a municipality to use such services.

Currently, the key element of a compliance strategy is enforcement through a penalty. There are no direct incentives for improving operation and maintenance programs. A possible alternative to noncompliance penalties is a requirement that municipalities utilize operational assistance provided by qualified experts, if their treatment plants are not performing satisfactorily. Partial federal or state funding of such assistance would increase the acceptance of this approach.

SECTION 10

POTENTIAL FOR IMPROVED PLANT PERFORMANCE

As noted previously in this report, during each preliminary evaluation performance data from available plant operating records were collected and compiled. Complete performance records were not available for all 30 plants, but whenever possible, performance data from the individual facilities were analyzed in terms of 30-day average concentrations and compared with the limitations set forth in the plant's NPDES permit. The number of times that the 30-day average concentrations of major constituents exceeded the permit requirements was determined. Table 14 shows a distribution of the study plants with respect to the percentage of time that the reported effluent parameters were not in compliance with the permitted 30-day average concentrations. As the table indicates, the 30-day average effluent concentrations at 8 plants exceeded the BOD_5 limit for the respective facility more than 60 percent of the time. Four plants exceeded the BOD_5 limit 40 percent to 60 percent of the time. Also, more than half of the plants surveyed violated individual suspended solids limits at least 40 percent of the time. Compliance with fecal coliform limits was relatively good, with 75 percent of the plants for which data were available showing noncompliance less than 20 percent of the time.

Table 15 presents a summary of effluent characteristics for the 30 plants studied in the preliminary evaluation phase. The table summarizes the flow, and effluent BOD_5 and suspended solids data reported by the plants for the year preceding the survey. Inasmuch as the BOD_5 and suspended solids tests were frequently conducted improperly or with poor technique by the plant personnel, the reliability and/or representativeness of these data is questionable. Although composite sampling was normally a provision of the NPDES permit of each facility, compositing was rarely conducted. Improper sampling techniques were frequently noted by study personnel with respect to BOD_5 examinations. In addition, the analytical methods employed were often not those approved by EPA. For these reasons, the information in Table 15 may not accurately reflect actual conditions, but the table is based on the only data available for each plant. The data suggest that the facilities examined during the preliminary evaluation phase were discharging average daily BOD_5 and suspended solids loads of 7,290 Kg/d (16,080 lb/d) and 8,720 Kg/d (19,235 lb/d), respectively. Table 16 sets forth the allowable effluent BOD_5 and suspended solids loads based on the present average annual flow and NPDES permit limitations. As the table indicates, at the present average flow an aggregate total BOD_5 and suspended solids load of 9,490 Kg/d (20,915 lb/d) and (8,700 Kg/d (19,185 lb/d), respectively, could be discharged by the plants while still remaining within the permit limitations.

As a result of each preliminary evaluation, various recommendations were made for improving the administration, operation, or maintenance of each

TABLE 14. DISTRIBUTION OF PLANTS WITH RESPECT TO NONCOMPLIANCE WITH NPDES PERMIT STANDARDS

	PERCENTAGE OF NONCOMPLIANCE OF PERFORMANCE TESTS WITH 30-DAY AVERAGE LIMITATIONS											
	BOD_5				Suspended Solids				Fecal Coliform			
Plant No.	<60%	40-60%	20-40%	0-20%	<60%	40-60%	20-40%	0-20%	<60%	40-60%	20-40%	0-20%
042												
037												
102												
005				✓		✓						
086												
032												
059	✓				✓							✓
024			✓		✓				✓			
038	✓				✓							✓
093			✓				✓			✓		
082				✓								
006			✓					✓				
048		✓			✓							
089				✓	✓							✓
095	✓							✓			✓	
120				✓				✓				✓
034		✓				✓			✓			
068				✓			✓		✓			
071	✓					✓						✓
077			✓					✓				✓
021				✓				✓				
026			✓		✓							✓
046		✓						✓				
114				✓				✓				✓
106			✓		✓							✓
053				✓			✓					✓
074	✓					✓						✓
083					✓							✓
066				✓			✓					✓
078			✓					✓				
	5	3	7	9	8	4	4	8	3	1	1	13

TABLE 15. CURRENT ANNUAL EFFLUENT CHARACTERISTICS OF PRELIMINARY EVALUATION PLANTS

Plant No.	Average Flow (m^3/d)	Average Flow (mgd)	Average BOD$_5$ Conc. (mg/l)	Average BOD$_5$ Load. (Kg/day)	Average BOD$_5$ Load. (lb./day)	Average S. S. Conc. (mg/l)	Average S. S. Load. (Kg/day)	Average S. S. Load. (lb./day)	NPDES Permit Compliance	
									BOD	S.S.
042	1,320	0.35	28	36	80	52	68	150	Yes	No
037	1,930	0.51	16	32	70	48	93	205	Yes	No
102	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	-	-
005	570	0.15	14	9	20	33	18	40	Yes	No
086	1,480	0.39	30	45	100	33	48	105	Yes	No
032	11,360	3.0	12	136	300	21	238	525	No	No
059	34,820	9.2	32	1,113	2,455	35	1,218	2,685	No	No
024	4,920	1.3	17	84	185	49	243	535	Yes	No
038	17,030	4.5	95	1,617	3,565	37	630	1,390	Yes	Yes
093	22,330	5.9	22	490	1,080	41	914	2,015	Yes	No
082	4,240	1.12	16	68	150	26	127	280	Yes	Yes
006	2,080	0.55	22	45	100	21	43	95	Yes	Yes
048	15,330	4.05	35	535	1,180	59	905	1,995	No	No
089	1,400	0.37	15	20	45	47	66	145	Yes	No
095	1,140	0.30	36	41	90	24	27	60	No	Yes
120	10,300	2.72	5	52	115	10	105	231	Yes	Yes
034	1,210	0.32	22	27	60	30	36	80	Yes	Yes
068	1,850	0.49	8	16	35	21	39	86	Yes	Yes
071	4,350	1.15	107	465	1,025	30	132	290	No	Yes
077	4,540	1.2	29	132	290	19	86	190	Yes	Yes
021	3,330	0.88	6	20	45	7	23	50	Yes	Yes
026	24,980	6.6	37	923	2,035	62	1,549	3,415	Yes	No
046	910	0.24	30	27	60	19	17	38	Yes	Yes
114	40,500	10.7	7	284	625	10	404	890	Yes	Yes
106	11,810	3.12	25	295	650	44	519	1,145	Yes	No
053	8,330	2.2	22	184	405	25	209	460	Yes	Yes
074	2,460	0.65	38	93	205	23	56	124	No	Yes
083	33,420	8.83	12	401	885	25	836	1,842	Yes	No
066	1,250	0.33	15	18	40	21	25	55	Yes	Yes
078	3,330	0.88	25	84	185	15	50	110	Yes	Yes
	272,520	72.0	26.8	7,294	16,080	32.0	8,725	19,235		

TABLE 16. DISCHARGE POLLUTANT LOADS BASED ON NPDES PERMIT LEVELS AND PRESENT AVERAGE ANNUAL FLOW

Plant No.	Average Annual Flow (m^3d)	Average Annual Flow (mgd)	Permitted BOD_5 Conc. (mg/1)	Permitted BOD_5 Loading (Kg./day)	Permitted BOD_5 Loading (1b./day)	Permitted S.S. Conc. (mg/1)	Permitted S. S. Loading (Kg/day)	Permitted S. S. Loading (1b./day)
042	1,320	0.35	30	41	90	40	54	120
037	1,930	0.51	30	59	130	30	59	130
102	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)
005	570	0.15	30	18	40	30	18	40
086	1,480	0.39	30	45	100	30	45	100
032	11,360	3.0	8	91	200	20	227	500
059	34,820	9.2	21	730	1,610	25	871	1,920
024	4,920	1.3	30	147	325	30	147	325
038	17,030	4.5	115	1,957	4,315	50	850	1,875
093	22,330	5.9	24	535	1,180	39	871	1,920
082	4,240	1.12	30	127	280	30	127	280
006	2,080	0.55	30	64	140	30	64	140
048	15,330	4.05	30	460	1,015	30	460	1,015
089	1,400	0.37	16	23	50	30	43	95
095	1,140	0.30	20	23	50	30	34	75
120	10,300	2.72	30	308	680	24	247	545
034	1,210	0.32	30	36	80	30	36	80
068	1,850	0.49	15	27	60	25	45	100
071	4,350	1.15	30	132	290	30	132	290
077	4,540	1.2	30	136	300	30	136	300
021	3,330	0.88	30	100	220	30	100	220
026	24,980	6.6	40	998	2,200	40	998	2,200
046	910	0.24	30	27	60	30	27	60
114	40,500	10.7	45	1,821	4,015	45	1,821	4,015
106	11,810	3.12	27	320	705	25	295	650
053	8,330	2.2	30	249	550	30	249	550
074	2,460	0.65	30	73	160	30	73	160
083	33,420	8.83	24	803	1,770	16	535	1,180
066	1,250	0.33	30	36	80	30	36	80
078	3,330	0.88	30	100	220	30	100	220
	272,520	72.0	34.8	9,487	20,915	32.0	9,702	19,185

wastewater treatment facility. Appendix C presents a summary of the major specific recommendations set forth in each of the preliminary evaluation reports. As indicated in the appendix, some of the more common recommendations involved establishment of an effective process monitoring and process control program, preparation of a comprehensive operations manual, improvement of spare parts inventory and routine maintenance, or operator training in process control. Other actions frequently recommended, including facility expansion or infiltration/inflow reduction, would require significant capital expenditures and are, therefore, beyond the scope and intent of this study. Presumably, if the O&M related recommendations were properly implemented, improvements in plant performance would be realized. Accordingly, if these recommendations were carried out, the plants would achieve their optimal degree of performance, beyond which further improvement would not be feasible without upgrading the existing facilities. Table 17 sets forth estimates of effluent quality for each plant attainable through the implementation of all administrative, operational, and maintenance-related modifications, presented in each of the preliminary evaluations. These estimates of attainable effluent quality were developed with professional judgement on the basis of knowledge of the systems evaluated and of accepted performance standards for properly designed systems. As shown in the table, total effluent BOD_5 and suspended solids loadings for the combined 30 plants could be reduced to 5,491 kg/d (12,105 lb/d) and 6,053 Kg/d (13,345 lb/d), respectively, thereby reducing the present average effluent BOD_5 and suspended solids loads to the environment by 1,803 Kg/d (3,975 lb/d) and 2,672 Kg/d (5,890 lb/d), respectively.

Realistically, the recommendations should not be expected to be implemented by plant operating or administrative personnel to the extent that an effluent of better quality than that called for by the permit would be consistently produced. There is no incentive to produce an effluent of significantly better quality than defined by effluent concentrations set forth in the permit and, therefore, Table 17 may show an overestimate of reduction in total pollutants discharged. With this fact in mind, in those cases where implementation of the recommended operational changes could result in an effluent quality exceeding that required by the permit, the NPDES permit limits have been substituted as the characteristics of the effluent that are likely to be attained. The results of this analysis are shown in Table 18. As the table indicates, through implementation of the recommendations to the point of achieving the NPDES limits (wherever possible), the BOD_5 and suspended solids loads currently discharged to the environment by the study plants, could be reduced by 1,365 Kg/d (3,010 lb/d) and 1,803 Kg/d (3,975 lb/d), respectively. On an annual basis, the reductions would be approximately 0.5 million Kg (1.1 million pounds) of BOD_5 and 0.635 million Kg (1.4 million pounds) of suspended solids

In terms of improving compliance with effluent limitations, it is estimated that 26 of the preliminary evaluation plants would be capable of meeting their respective BOD_5 limitations by implementing the recommendations to the point of achieving NPDES permit standards. Similarly, 24 plants would meet their suspended solids limitations. Therefore, 85 percent to 90 percent of the plants studied would be in continuous compliance with their respective NPDES permits. Table 19 summarizes the potential for improved performance at

TABLE 17. EFFLUENT CHARACTERISTICS ATTAINABLE THROUGH IMPLEMENTATION OF RECOMMENDATIONS

Plant No.	Average Annual Flow (m^3/d)	Average Annual Flow (mgd)	BOD_5 Conc. (mg/1)	BOD_5 Load. (Kg/day)	BOD_5 Load. (1b./day)	S. S. Conc. (mg/1)	S. S. Load. (Kg/day)	S. S. Load. (1b./day)	NPDES Permit Compliance BOD	NPDES Permit Compliance S. S.
042	1,320	0.35	28	36	80	30	41	90	Yes	Yes
037	1,930	0.51	16	32	70	30	59	130	Yes	Yes
102	(N/A)	(N/A)	20	-	-	20	-	-	-	-
005	570	0.15	14	9	20	20	11	25	Yes	Yes
086	1,480	0.39	20	29	65	20	29	65	Yes	Yes
032	11,360	3.0	10	113	250	10	113	250	No	Yes
059	34,820	9.2	20	696	1,535	20	696	1,535	Yes	Yes
024	4,920	1.3	17	84	185	18	88	195	Yes	Yes
038	17,030	4.5	60	1,020	2,250	25	426	940	Yes	Yes
093	22,330	5.9	20	447	985	30	669	1,475	Yes	Yes
082	4,240	1.12	16	68	150	26	109	240	Yes	Yes
006	2,080	0.55	20	41	90	20	41	90	Yes	Yes
048	15,330	4.05	35	535	1,180	40	612	1,350	No	No
089	1,400	0.37	15	20	45	40	57	125	Yes	No
095	1,140	0.30	25	29	65	21	25	55	No	Yes
120	10,300	2.72	5	52	115	10	102	225	Yes	Yes
034	1,210	0.32	22	27	60	24	29	65	Yes	Yes
068	1,850	0.49	8	16	35	20	36	80	Yes	Yes
071	4,350	1.15	30	132	290	30	132	290	Yes	Yes
077	4,540	1.2	25	113	250	19	86	190	Yes	Yes
021	3,330	0.88	6	20	45	7	23	50	Yes	Yes
026	24,980	6.6	30	748	1,650	45	1,123	2,475	Yes	No
046	910	0.24	30	27	60	19	18	40	Yes	Yes
114	40,500	10.7	7	283	625	10	404	890	Yes	Yes
106	16,810	3.12	15	177	390	17	200	440	Yes	Yes
053	8,330	2.2	20	166	365	15	125	275	Yes	Yes
074	2,460	0.65	26	64	140	23	57	125	Yes	Yes
083	33,420	8.83	12	401	885	20	657	1,470	Yes	No
066	1,250	0.33	15	18	40	20	25	55	Yes	Yes
078	3,330	0.88	25	84	185	15	50	110	Yes	Yes
	272,520	72.0	20.2	5,491	12,105	22.2	6,053	13,345		

TABLE 18. ANTICIPATED EFFLUENT CHARACTERISTICS WITH NPDES PERMIT LIMITS AS GOAL

Plant No.	Average Annual Flow (m^3/d)	Average Annual Flow (mgd)	BOD_5 Conc. (mg/1)	BOD_5 Load. (Kg/day)	BOD_5 Load. (lb./day)	S. S. Conc. (mg/1)	S. S. Load. (Kg/day)	S. S. Load (lb./day)	NPDES Permit Compliance BOD	NPDES Permit Compliance S. S.
042	1,320	0.35	28	36	80	40	54	120	Yes	Yes
037	1,930	0.51	16	32	70	30	59	130	Yes	Yes
102	(N/A)	(N/A)	24	-	-	24	-	-	-	-
005	570	0.15	14	9	20	30	18	40	Yes	Yes
086	1,480	0.39	30	45	100	30	45	100	Yes	Yes
032	11,360	3.0	10	113	250	20	227	500	No	Yes
059	34,820	9.2	21	730	1,610	25	871	1,920	Yes	Yes
024	4,920	1.3	17	84	185	30	147	325	Yes	Yes
038	17,030	4.5	60	1,021	2,250	30	510	1,125	Yes	Yes
093	22,320	5.9	22	490	1,080	39	871	1,920	Yes	Yes
082	4,240	1.12	16	68	150	26	109	240	Yes	Yes
006	2,080	0.55	22	45	100	21	43	95	Yes	Yes
048	15,330	4.05	35	535	1,180	40	612	1,350	No	No
089	1,400	0.37	15	20	45	40	57	125	Yes	No
095	1,140	0.30	28	32	70	24	27	60	No	Yes
120	10,300	2.72	5	52	115	10	104	230	Yes	Yes
034	1,210	0.32	22	27	60	30	36	80	Yes	Yes
068	1,850	0.49	8	16	35	21	39	85	Yes	Yes
071	4,350	1.15	30	132	290	30	132	290	Yes	Yes
077	4,540	1.2	29	132	290	19	86	190	Yes	Yes
021	3,330	0.88	6	20	45	7	23	50	Yes	Yes
026	24,980	6.6	37	923	2,035	45	1,123	2,475	Yes	No
046	910	0.24	30	27	60	19	18	40	Yes	Yes
114	40,500	10.7	7	283	625	10	404	890	Yes	Yes
106	11,810	3.12	25	295	650	25	295	650	Yes	Yes
053	8,330	2.2	22	184	405	25	209	460	Yes	Yes
074	2,460	0.65	30	73	160	23	57	125	Yes	Yes
083	33,420	8.83	12	401	885	20	669	1,475	Yes	No
066	1,250	0.33	15	18	40	21	27	60	Yes	Yes
078	3,330	0.88	25	84	185	15	50	110	Yes	Yes
	272,520	72.0	21.7	5,928	13,070	25.6	6,922	15,260		

TABLE 19. IMPROVED PERFORMANCE EVALUATION

	BOD_5 (kg/day)	BOD_5 (lb/day)	S.S. (Kg/day)	S.S. (lb/day)
Current Effluent Characteristics	7,294	16,080	8,725	19,235
NPDES Permit Levels Based on Present Flow Conditions	9,487	20,915	8,702	19,185
Effluent Characteristics Attainable Through Implementation of Recommendations	5,491	12,105	16,053	13,345
Reduction in Pollutant Loading Through Implementation of Recommendations	1,803	3,975	2,672	5,890
Anticipated Effluent Characteristics with NPDES Permit Limits as Goal	5,928	13,070	6,922	15,260
Reduction in Pollutant Loading Through Implementation of Recommendations with NPDES Permit Limits as Goal	1,365	3,010	1,803	3,975
Percent of Plants Currently Complying with NPDES Permit Limits (According to Plant Records)		79%		55%
Anticipated Compliance with NPDES Permit Limits as Goal		90%		86%

the facilities studied under the preliminary evaluation phase, as well as the potential impact on pollutant loadings to the environment that would be effected by such improved performance.

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TABLE A-1. SUMMARY OF SITE VISIT DATA - GENERAL INFORMATION

Plant No.	Design Flow (mgd)	Type Of Treatment*	Present Av.Flow (mgd)	Present Peak Flow (mgd)	Service Population	Separate Collection System	Point Of Discharge	Year Of Construction	Year Of Most Recent Upgrading	Character Of Waste	Impact Of Industrial Wastewaters	Impact Of Infiltration/Inflow	Prelim. Evaluation Performed
001	18.0	Tr Fil	27.5	42.0	188,000	--	Potomac R	1956	By 1977	Domestic	0	2	
002	7.5	Con A S	7.2	10.5	25,000	No	Lt Juniata R	1951	--	<10% IW	1	2	
003	>5.0	Con A S	4.0	--	38,000	--	Beaver Dam Br	1954	1976	30% IW	2	1	
004	10.0	Con A S	5.0	--	--	--	--	--	1975	--	-	-	
005	0.25	Ext Aer	0.15	0.6	2,700	Yes	Laurel Ck	1970	--	Domestic	0	2	Yes
006	0.5	Con A S	0.5	1.0	7,000	Yes	Tevebaugh R	1947	1973	Domestic	0	1	Yes
007	0.8	2-St A S	1.3	--	7,000	Yes	Martins Ck	--	1960	Domestic	0	2	
008	0.8	Con Stab	0.18	--	800	Yes	Beaver Ck	1967	--	Domestic	0	2	
009	0.6	Tr Fil	0.2	0.35	2,000	--	Bottle Br	1935	1969	Domestic	0	1	
010	0.439	Aer Lag	0.25	--	--	Yes	Town Run	1968	--	Domestic	0	1	
011	2.7	Tr Fil	2.7	5.0	--	Yes	Piney Fork Ck	1958	--	Domestic	0	2	
012	2.25	Tr Fil	2.25	--	10,000	--	Delaware R	--	1964	10% IW	1	-	
013	0.351	Tr Fil	0.5	--	2,700	No	Kishocoquil Ck	1960	1965	Domestic	0	2	
014	5.0	Tr Fil	6.5	20.0	39,000	No	Connoquenes Ck	1925	1963	Domestic	0	2	
015	8.0	Con A S	--	--	--	No	--	--	--	--	-	-	
016	0.4	Con Stab	0.45	0.77	--	Yes	Moon Run	1963	1973	Domestic	0	2	
017	0.25	Ext Aer	0.15	--	--	Yes	--	1971	--	Domestic	0	0	
018	0.15	Con Stab	0.11	--	1,000	Yes	Chesapeake Bay	1969	--	Domestic	0	0	
019	0.265	Aer Lag	0.28	0.30	1,400	--	Mid Fk Holst R	1965	1970	Domestic	0	-	
020	0.2	Act Sl	0.15	--	1,850	Yes	Leggetts Ck	1969	1974	Domestic	0	1	
021	1.25	Ext Aer	0.88	1.7	9,000	No	Leggetts Ck	1970	--	Domestic	0	2	Yes
022	0.021	Ext Aer	0.02	0.05	500	Yes	Scrubgrass Ck	1973	--	Domestic	0	1	
023	1.65	Con A S	0.9	4.0	12,000	Partial	Panthers Ck	1965	--	Domestic	0	1	
024	1.3	Con A S	1.3	2.5	17,500	Yes	Schuylkill R	1952	--	<10% IW	1	2	Yes
025	0.4	Con Stab	0.75	1.25	3,000	No	Allegheny R	1968	--	10% IW	2	2	
026	8.5	Con Stab	7.5	15.0	50,000	--	Patapsco R	1957	1969	10-20% IW	2	2	Yes
027	0.5	Con Stab	0.25	--	1,800	Yes	Brush Ck	1973	--	Domestic	0	1	
028	0.3	Tr Fil	--	--	--	--	--	--	--	--	-	-	
029	1.4	Tr Fil	1.75	3.0	7,000	--	Mount Run	1935	1966	Domestic	0	2	
030	24.0	O_2 A S	18.4	22.7	49,000	Yes	Dan R	1976	--	60% IW	2	0	
031	0.3	Con Stab	0.25	--	1,500	Yes	Dogwood Run	1968	--	Domestic	0	2	
032	4.0	Ext Aer	3.7	7.5	30,000	No	Brandywine Ck	1973	--	20% IW	2	1	Yes
033	2.2	Tr Fil	3.0	6.0	17,000	Yes	Sandy Lick Ck	1961	--	<10% IW	0	2	
034	0.25	Ext Aer	0.22	0.75	7,000	Yes	Blair Gap Run	1964	--	Domestic	0	1	Yes
035	5.0	Tr Fil	5.5	--	45,000	No	Delaware R	1952	--	10% IW	1	2	

(continued)

TABLE A-1 (continued)

Plant No.	Design Flow (mgd)	Type Of Treatment*	Present Av.Flow (mgd)	Present Peak Flow (mgd)	Service Population	Separate Collection System	Point Of Discharge	Year Of Construction	Year Of Most Recent Upgrading	Character Of Waste	Impact Of Industrial Wastewaters	Impact Of Infiltration/Inflow	Prelim. Evaluation Performed
036	0.43	Tr Fil	0.45	0.6	3,100	Yes	Sinnemahon Ck	1962	--	<5% IW	0	2	
037	0.5	Ext Aer	0.34	1.5	5,700	No	Ohio R	1965	--	Domestic	1	0	Yes
038	7.0	Tr Fil	4.1	7.6	29,300	Yes	Monocacy R	1936	1969	10% IW	2	1	Yes
039	0.5	Tr Fil	0.18	0.3	2,200	Yes	Wicomico R	1973	--	Domestic	0	0	
040	0.25	Ext Aer	--	--	--	Yes	--	1963	--	Domestic	0	0	
041	0.1	Tr Fil	--	--	--	--	--	--	--	--	-	-	
042	0.55	Aer Lag	0.35	0.46	1,400	Yes	Trib Anna R	1969	--	60% IW	2	2	Yes
043	5.0	Con A S	2.2	4.5	19,000	Yes	Bull Run	1968	1973	Domestic	0	1	
044	8.0	Con A S	4.5	12.0	--	--	--	1924	--	--	-	1	
045	0.3	Con Stab	0.15	--	1,500	Yes	N Piney Run	1971	--	Domestic	-	-	
046	0.21	Ox Ditch	0.20	0.34	2,100	Yes	Brubaker Run	1970	--	Domestic	0	2	Yes
047	0.05	Tr Fil	--	--	--	Yes	--	--	--	Domestic	0	1	
048	3.0	Act. Sl	2.5	4.0	25,000	--	Stony Run	1973	--	<10% IW	0	1	Yes
049	0.5	Ext Aer	0.24	--	1,400	--	Mates Run	--	1968	Domestic	0	2	
050	15.0	Con A S	11.50	--	150,000	--	--	1966	1976	Domestic	0	-	
051	0.11	Ext Aer	0.15	0.20	900	Yes	Shenango R	1968	--	Domestic	0	2	
052	0.075	Act Sl	0.06	0.09	<2,500	--	--	--	--	>25% IW	2	1	
053	3.0	Con A S	2.0	--	15,000	No	Lackawanna R	1972	--	Domestic	0	1	Yes
054	0.8	Tr Fil	0.8	2.7	5,000	No	West Run	1967	--	Domestic	0	2	
055	0.225	Tr Fil	0.1	--	1,200	--	Seays Ck	1931	1958	Domestic	0	2	
056	1.1	Tr Fil	--	--	5,500	Yes	--	--	1962	Domestic	0	1	
057	0.46	Tr Fil	0.45	1.0	2,400	Yes	Elk Ck	1965	--	--	1	2	
058	9.5	Con Stab	11.0	--	--	Yes	--	1933	1963	>25% IW	2	2	
059	12.0	Con Stab	9.2	12.2	60,000	No	Conestoga Ck	1933	1970	10% IW	0	1	Yes
060	1.8	Tr Fil	1.8	--	18,500	--	W Neshaminy Ck	1948	--	<10% IW	0	2	
061	0.2	Tr Fil	--	--	--	--	--	--	--	Domestic	0	2	
062	0.24	Ext Aer	0.13	0.2	1,000	Yes	Shades Run	--	--	--	1	0	
063	36.0	Con Stab	16.0	30.0	150,000	Yes	Ponick Bay	1970	1976	Domestic	0	1	
064	0.271	Ext Aer	0.15	0.25	2,400	Yes	Wisconisco Ck	1967	--	Domestic	0	1	
065	0.872	Tr Fil	0.70	1.20	14,500	Yes	Occoquan R	1963	1973	Domestic	0	1	
066	1.0	Con Stab	0.40	0.65	8,000	No	Tioga R	1969	--	Domestic	0	0	Yes
067	1.7	Tr Fil	1.37	--	--	Yes	--	1961	--	Domestic	0	2	
068	0.5	Con A S	0.35	0.80	2,500	Yes	Plum Ck	--	1969	Domestic	0	2	Yes
069	0.45	Tr Fil	0.25	--	3,500	--	Plum Ck	--	1972	Domestic	0	0	
070	0.4	Tr Fil	0.31	0.70	3,800	Yes	Lt Neshan Ck	1930	1968	Domestic	0	2	
071	2.5	Tr Fil	1.25	2.5	6,000	No	Ohio R	1960	1974	10% IW	2	0	Yes
072	2.5	Con A S	0.55	--	9,500	Yes	Conestoga Ck	--	1965	Domestic	0	0	
073	0.30	Ext Aer	0.25	--	2,500	Yes	Monongahela R	1968	--	Domestic	0	0	
074	1.00	Tr Fil	0.65	1.7	4,000	Yes	Mill Ck	1940	1959	Moderate IW	0	0	Yes
075	0.49	Tr Fil	0.40	0.85	4,500	Yes	Neshaminy Ck	1964	--	<5% IW	0	0	

(continued)

TABLE A-1 (continued)

Plant No.	Design Flow (mgd)	Type Of Treatment*	Present Av.Flow (mgd)	Present Peak Flow (mgd)	Service Population	Separate Collection System	Point Of Discharge	Year Of Construction	Year Of Most Recent Upgrading	Character Of Waste	Impact Of Industrial Wastewaters	Impact Of Infiltration/Inflow	Prelim. Evaluation Performed
076	9.75	Con A S	7.2	--	--	--	Schuylkill R	1968	--	10% IW	0	0	
077	1.75	TF/RBD	0.9	3.8	10,000	Yes	Youghiogheny R	1969	1975	Domestic	0	1	Yes
078	1.0	Con A S	0.9	2.5	8,000	No	Allegheny R	1961	--	20% IW	2	1	Yes
079	0.29	Ext Aer	0.09	--	--	No	--	1965	--	Domestic	0	-	
080	0.35	Con Stab	0.45	0.90	2,500	Yes	Mahamon Ck	1966	--	Domestic	0	2	
081	0.44	Ext Aer	0.15	--	--	--	--	1964	--	Domestic	0	-	
082	0.95	Con Stab	1.1	1.9	3,600	Yes	Walty Ck Trib	1961	1970	50% IW	2	1	Yes
083	15.0	Con A S	8.0	--	60,000	Partial	Appomattox R	1956	1974	10% IW	0	1	Yes
084	0.43	Tr Fil	0.55	1.0	2,500	No	Allegheny R	1969	--	<10% IW	2	1	
085	0.15	Con Stab	0.09	0.15	500	Yes	Susquehanna R	1972	--	Domestic	0	0	
086	0.5	Con Stab	0.39	0.5	4,000	No	Cherry R	1963	--	Domestic	0	1	Yes
087	0.22	Con Stab	0.10	0.15	950	--	Choptank R	1909	1970	Domestic	0	0	
088	35.0	Con A S	27.7	50.0	177,000	--	Roanoke R	1952	1977	50% IW	2	2	
089	0.60	Con Stab	0.40	--	3,300	Yes	Spring Ck	1966	--	>10% IW	1	2	Yes
090	0.80	Tr Fil	0.43	0.60	3,000	Yes	Pigg R	1968	--	Domestic	0	2	
091	0.54	Tr Fil	0.35	--	4,200	Yes	Schuylkill R	1950	--	>25% IW	2	-	
092	0.125	Tr Fil	--	--	--	--	--	--	--	--	-	-	
093	10.0	CS/CAS	5.9	9.8	60,000	Yes	Lt Patuxent R	1965	1975	Domestic	0	1	Yes
094	1.35	Con A S	0.65	2.0	6,000	No	Ohio R	1958	1972	Domestic	0	1	
095	0.35	Con Stab	0.34	--	3,000	Yes	Spring Ck	--	1972	10% IW	0	-	Yes
096	0.3	Ext Aer	0.23	0.35	3,000	Yes	Potato Ck	--	1968	Domestic	0	1	
097	0.2	Ext Aer	0.5	--	--	Yes	--	1966	--	Domestic	0	2	
098	0.34	Con A S	--	--	<2,500	--	--	1965	--	Domestic	0	-	
099	4.2	Tr Fil	2.0	5.0	50,000	Yes	Romney Ck	1969	--	Domestic	0	0	
100	1.0	Tr Fil	2.0	--	6,300	--	Cokes Ck	--	1959	Domestic	0	2	
101	0.4	Con Stab	0.006	--	1,200	Yes	Deer Ck Trib	1974	--	Domestic	0	0	
102	0.125	Con Stab	--	--	1,050	Yes	Straight Fk	1969	--	Domestic	0	2	Yes
103	0.3	Ext Aer	0.15	--	--	--	--	1956	--	Domestic	0	1	
104	2.0	Tr Fil	1.5	--	9,700	Yes	Nensemond R	1959	1974	30% IW	2	1	
105	0.7	Tr Fil	0.85	1.50	4,200	Yes	Clinch R	1966	--	Domestic	0	2	
106	7.0	Con A S	3.5	--	30,400	Yes	Lackawanna R	1969	--	30% IW	2	0	Yes
107	0.5	Tr Fil	0.35	1.40	2,800	Yes	Big Hunting Ck	1968	--	<10% IW	0	1	
108	0.11	Ox Ditch	--	--	--	--	--	--	--	--	-	-	
109	2.2	Con Stab	2.1	--	--	--	Wissahickon Ck	--	1973	40% IW	0	0	
110	5.0	Tr Fil	4.5	--	20,000	Yes	Trout Run	--	1968	<10% IW	0	0	
111	0.5	Tr Fil	0.5	2.0	4,500	--	Grand Run	1959	1977	Domestic	0	2	
112	4.0	Tr Fil	2.5	--	17,500	Partial	S Fk Potomac R	1955	1968	50% IW	2	0	
113	1.5	Tr Fil	1.2	--	6,000	--	Goose Ck	--	1954	50% IW	2	0	
114	14.0	O_2 A S	12.5	16.0	140,000	Yes	Potomac R	1954	1971	<10% IW	0	1	Yes
115	0.3	Tr Fil	--	--	--	Yes	--	1951	--	--	-	1	

(continued)

TABLE A-1 (continued)

Plant No.	Design Flow (mgd)	Type Of Treat- ment*	Present Av.Flow (mgd)	Present Peak Flow (mgd)	Service Pop- ulation	Separate Collection System	Point Of Discharge	Year Of Con struction	Year Of Most Recent Upgrading	Character Of Waste	Impact Of Industrial Wastewaters	Impact Of Infiltra- tion/Inflow	Prelim. Evaluation Performed
116	2.0	Aer Lag	1.0	--	--	Yes	Stoney Ck	--	--	Domestic	0	1	
117	0.3	Con Stab	0.3	--	2,000	--	--	--	--	<10% IW	0	-	
118	1.5	Con Stab	1.0	1.5	6,000	Yes	Occoquan Ck	--	1972	Domestic	0	0	
119	0.75	Con Stab	0.45	--	--	--	--	--	--	--	-	-	
120	3.0	TF/CAS	2.7	7.2	20,000	Yes	Wyomissing Ck	--	1970	50% IW	2	1	Yes

* Tr Fil	Trickling Filter
Con A S	Conventional Activated Sludge
Con Stab	Contact-Stabilization
Ext Aer	Extended Aeration
2-St A S	2-Stage Activated Sludge
Act Sl	Activated Sludge
Aer Lag	Aerated Lagoon
O_2 A S	Pure Oxygen Activated Sludge
Ox Ditch	Oxidation Ditch
TF/RBD	Trickling Filter/Rotating Bio Disc
CS/CAS	Contact-Stabilization/ Conventional Activated Sludge
CMAS	Complete Mix Activated Sludge
TR/CAS	Trickling Filter/ Conventional Activated Sludge

Rating	Interpretation
3	Plant is deficient in this area. Capability is nonexistent. Considerable problems result.
2	Plant may be deficient in this area. Capability is inadequate. Some problems result.
1	Plant may be deficient in this area. Capability is marginally adequate. Little or no problems result.
0	No apparent deficiencies exist. Capability appears adequate. No problems are apparent.

TABLE A-2. SUMMARY OF SITE VISIT DATA - OPERATIONS

Plant No.	Staff Size	Staff Certification	Staff Training	Treatment Understanding	Analytical Capabilities	Process Monitoring	Performance Monitoring	Process Control	Technical References	Consulting Engineer
001	0	0	0	0	0	0	0	1	0	1
002	0	1	-	0	1	1	0	-	-	1
003	0	0	0	0	0	0	0	0	1	1
004	-	-	-	-	-	-	-	-	-	-
005	0	2	2	2	1	2	1	2	2	-
006	2	0	1	1	0	1	0	1	1	1
007	0	0	0	2	1	1	2	2	2	2
008	3	1	2	2	3	3	2	3	2	2
009	0	0	0	0	1	2	3	3	2	2
010	1	1	1	1	1	0	0	1	1	1
011	0	0	0	0	0	1	0	1	-	1
012	0	0	1	1	1	1	1	1	1	1
013	0	0	0	0	0	1	0	1	1	1
014	0	1	-	1	0	1	0	1	-	1
015	-	-	-	-	0	0	0	0	-	-
016	0	0	-	0	0	1	0	2	-	1
017	0	0	0	0	0	-	0	-	-	-
018	1	1	1	1	0	1	0	1	-	1
019	0	0	1	1	0	1	0	1	1	1
020	0	0	0	0	1	1	1	1	-	1
021	0	0	0	1	1	2	1	2	2	1
022	2	0	2	2	3	3	3	2	2	3
023	0	0	0	0	0	1	0	1	-	-
024	0	1	1	1	2	2	2	2	2	1
025	0	0	1	1	2	2	0	2	-	0
026	0	0	0	0	1	2	1	2	1	1
027	0	0	0	0	0	0	0	-	-	1
028	-	-	-	-	-	-	-	-	-	-
029	0	0	2	2	0	0	0	2	1	0
030	0	0	0	0	0	0	0	0	0	0
031	0	1	2	2	2	2	0	2	-	-
032	0	0	0	1	0	2	0	2	1	0
033	0	0	0	0	0	0	0	0	-	-
034	0	0	1	1	2	2	2	2	1	1
035	0	0	0	0	0	0	0	0	0	0

(continued)

TABLE A-2 (continued)

Plant No.	Staff Size	Staff Certification	Staff Training	Treatment Understanding	Analytical Capabilities	Process Monitoring	Performance Monitoring	Process Control	Technical References	Consulting Engineer
036	0	1	0	0	0	1	0	0	-	1
037	0	2	2	2	2	2	2	3	2	2
038	0	0	0	0	0	1	0	0	1	0
039	0	0	0	0	0	1	0	0	1	1
040	2	0	3	3	2	2	2	3	-	2
041	1	-	-	-	-	-	-	-	-	-
042	2	0	0	1	1	2	1	2	3	2
043	0	0	0	0	0	0	0	0	0	-
044	-	-	-	-	-	-	-	-	-	-
045	0	0	0	0	0	1	0	1	-	1
046	3	1	2	0	2	2	1	2	1	2
047	2	-	2	2	2	2	-	2	-	-
048	0	0	0	0	0	0	0	0	1	0
049	0	0	0	0	0	1	0	1	-	0
050	0	0	0	0	2	2	0	2	0	-
051	0	2	2	2	2	2	1	2	-	2
052	-	-	-	-	-	-	-	-	-	-
053	0	0	0	0	0	1	0	1	1	0
054	0	0	0	0	0	1	0	1	0	0
055	0	1	1	1	2	1	2	2	-	-
056	0	0	0	0	1	1	1	1	1	1
057	0	0	0	0	-	-	-	-	-	-
058	0	0	0	0	0	0	0	0	-	-
059	0	0	0	1	0	0	0	2	0	0
060	0	0	0	0	0	-	0	-	-	-
061	-	-	-	-	-	-	-	-	-	-
062	2	1	0	0	-	2	-	2	-	-
063	0	0	0	0	0	0	0	0	0	0
064	0	0	0	0	1	1	1	1	-	-
065	0	1	0	0	1	1	0	0	-	0
066	1	0	0	1	0	0	0	0	1	1
067	0	0	1	0	0	0	0	0	-	-
068	2	1	2	2	2	2	2	2	2	2
069	0	1	1	1	1	1	1	1	-	1
070	0	0	-	0	0	-	0	-	-	1
071	0	1	1	0	0	0	0	2	1	0
072	1	1	0	0	0	0	0	0	-	0
073	0	0	0	0	0	1	0	1	1	1
074	2	0	0	0	0	0	0	0	1	0
075	-	-	-	-	-	-	-	-	-	-

(continued)

TABLE A-2 (continued)

Plant No.	Staff Size	Staff Certification	Staff Training	Treatment Understanding	Analytical Capabilities	Process Monitoring	Performance Monitoring	Process Control	Technical References	Consulting Engineer
076	0	0	0	0	0	0	0	0	-	1
077	0	0	0	0	0	0	0	0	0	0
078	1	0	0	0	0	0	0	1	1	0
079	0	1	1	1	2	2	0	2	-	-
080	3	2	1	1	2	2	2	2	-	-
081	3	3	2	2	2	3	1	3	2	2
082	1	1	1	0	0	2	1	2	1	1
083	0	1	0	0	0	1	0	1	0	1
084	0	0	0	0	0	0	0	0	-	1
085	1	0	0	0	1	0	0	0	1	3
086	3	2	2	2	2	2	1	3	1	3
087	1	0	0	0	0	1	0	1	0	1
088	0	0	0	0	0	0	0	0	0	0
089	0	0	2	1	1	2	1	2	1	0
090	0	0	1	0	0	0	0	0	1	0
091	2	1	-	2	2	2	1	2	2	2
092	-	-	-	-	-	-	-	-	-	-
093	0	0	1	0	0	0	0	2	2	0
094	0	0	0	0	0	0	0	1	-	-
095	0	0	0	0	1	0	0	0	1	0
096	1	0	1	1	0	1	0	1	1	0
097	3	3	2	2	2	2	0	3	3	2
098	0	0	-	1	1	1	1	1	-	-
099	0	0	0	0	0	1	0	1	-	1
100	0	0	0	0	0	1	1	1	-	0
101	0	0	0	0	0	-	0	-	-	-
102	2	2	3	3	3	3	3	3	3	3
103	0	0	-	1	2	2	2	2	-	1
104	0	0	0	0	1	0	0	0	-	0
105	0	0	0	0	0	1	0	0	-	0
106	1	1	1	0	0	1	0	1	1	0
107	0	0	0	0	0	1	0	1	-	0
108	-	-	-	-	-	-	-	-	-	-
109	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	1	0	1	0	1
111	0	0	0	0	0	1	0	1	1	0
112	0	0	0	0	0	0	0	0	0	0
113	0	0	1	0	0	1	0	0	1	-
114	0	0	0	0	0	0	0	1	1	0
115	1	3	2	2	3	3	3	3	-	-

(continued)

TABLE A-2 (continued)

Plant No.	Staff Size	Staff Certification	Staff Training	Treatment Understanding	Analytical Capabilities	Process Monitoring	Performance Monitoring	Process Control	Technical References	Consulting Engineer
116	1	0	0	1	0	0	0	1	1	1
117	0	0	0	0	1	1	1	0	-	0
118	0	0	0	0	1	0	0	0	-	-
119	-	-	-	-	-	-	-	-	-	-
120	0	0	0	1	0	0	0	1	0	0

Rating	Interpretation
3	Plant is deficient in this area. Capability is nonexistent. Considerable problems result.
2	Plant may be deficient in this area. Capability is inadequate. Some problems result.
1	Plant may be deficient in this area. Capability is marginally adequate. Little or no problems result.
0	No apparent deficiencies exist. Capability appears adequate. No problems are apparent.

TABLE A-3. SUMMARY OF SITE VISIT DATA - MAINTENANCE

Plant No.	Staff Capabilities	Age Of Equipment	Spare Parts Inventory	Preventive Maintenance	Emergency Provisions	Backup Unit Provisions	Technical References	Housekeeping Practices	Auxiliary Power Source
001	0	1	0	0	-	-	0	0	-
002	0	2	0	1	-	-	-	0	-
003	0	1	0	0	-	0	0	0	No
004	-	-	-	-	-	-	-	-	-
005	0	0	1	0	1	2	2	0	Yes
006	1	0	1	1	2	2	0	0	No
007	2	2	3	2	-	-	3	1	-
008	2	0	-	2	-	3	-	2	-
009	2	1	2	2	-	0	1	0	No
010	0	0	0	0	-	0	-	0	No
011	0	0	0	0	-	0	-	0	-
012	-	1	2	2	-	-	0	-	-
013	0	1	-	0	-	3	0	0	No
014	0	2	0	0	-	0	-	2	No
015	-	-	-	-	-	-	-	-	-
016	2	0	-	2	-	-	-	2	-
017	0	0	-	0	-	0	-	0	-
018	1	0	3	1	2	3	-	0	-
019	1	0	2	1	-	2	2	0	No
020	-	0	3	0	2	1	1	0	No
021	0	0	0	0	1	0	0	0	Yes
022	2	0	2	3	3	3	2	3	No
023	0	0	0	0	-	0	-	0	-
024	0	2	0	0	0	0	1	0	Yes
025	1	0	2	2	-	3	1	1	-
026	0	0	1	0	0	0	0	0	Yes
027	0	0	2	1	-	-	-	0	-
028	-	-	-	-	-	3	-	-	-
029	1	3	2	2	2	-	0	2	No
030	0	0	0	0	-	0	0	0	Yes
031	2	0	3	3	2	0	-	-	-
032	1	0	0	0	0	0	0	1	Yes
033	0	1	0	0	0	0	-	0	-
034	1	0	1	0	0	0	0	0	No
035	0	2	0	0	-	0	0	0	-

(continued)

TABLE A-3 (continued)

Plant No.	Staff Capabilities	Age Of Equipment	Spare Parts Inventory	Preventive Maintenance	Emergency Provisions	Backup Unit Provisions	Technical References	Housekeeping Practices	Auxiliary Power Source
036	1	1	2	2	-	2	-	1	-
037	0	0	0	0	0	1	1	0	No
038	0	1	0	0	0	1	1	0	No
039	0	0	0	0	-	0	1	0	No
040	1	1	2	1	2	0	2	1	No
041	-	-	-	-	-	-	-	-	-
042	2	1	1	2	1	0	1	1	No
043	0	0	2	0	-	0	0	0	-
044	-	-	-	-	-	-	-	-	-
045	0	0	0	0	0	0	-	0	Yes
046	2	1	2	2	1	3	0	2	Yes
047	3	-	3	3	-	3	-	2	-
048	1	0	1	1	1	1	1	0	No
049	2	0	2	2	-	3	-	1	No
050	0	0	2	0	0	0	0	0	Yes
051	0	0	1	0	-	3	-	0	-
052	-	-	-	-	-	-	-	-	-
053	1	0	2	0	1	0	1	0	Yes
054	0	0	2	1	-	3	-	0	-
055	2	3	3	2	2	3	3	2	No
056	0	1	1	2	1	0	-	-	-
057	0	1	2	1	-	2	-	0	-
058	-	-	-	2	-	-	-	-	-
059	1	1	1	0	1	0	0	1	No
060	0	2	-	0	-	0	-	1	-
061	-	-	-	-	-	-	-	-	-
062	0	0	0	1	3	2	-	1	No
063	0	0	0	0	-	0	0	0	Yes
064	0	0	1	2	-	1	-	0	No
065	0	2	2	1	-	0	-	1	-
066	0	0	0	0	1	1	1	0	No
067	0	1	0	0	-	0	-	0	-
068	1	0	0	1	1	0	2	0	No
069	0	2	-	0	-	1	-	0	-
070	0	0	0	0	-	-	-	0	-
071	0	1	1	0	0	1	0	0	No
072	0	-	0	0	-	-	-	0	-
073	0	0	0	0	-	-	-	0	-
074	2	2	1	2	0	1	1	2	No
075	-	-	-	-	-	-	-	-	-

(continued)

TABLE A-3 (continued)

Plant No.	Staff Capabilities	Age Of Equipment	Spare Parts Inventory	Preventive Maintenance	Emergency Provisions	Backup Unit Provisions	Technical References	Housekeeping Practices	Auxiliary Power Source
076	2	2	2	2	-	0	-	1	-
077	0	0	0	0	0	0	0	0	No
078	2	1	0	1	0	0	1	1	No
079	1	1	3	3	-	3	3	2	-
080	3	0	3	3	-	1	-	2	-
081	3	1	2	2	-	1	-	2	-
082	1	1	1	0	0	0	3	0	No
083	0	0	2	1	1	0	0	0	Yes
084	0	0	2	0	1	2	-	0	-
085	0	0	0	0	-	-	-	0	-
086	1	0	2	3	1	2	2	1	No
087	0	0	0	0	-	2	-	0	-
088	0	0	0	0	0	0	0	0	Yes
089	0	0	0	0	0	0	1	0	Yes
090	0	0	1	0	0	0	-	0	No
091	1	1	-	0	-	-	-	0	-
092	-	-	-	-	-	-	-	-	-
093	0	0	1	0	0	0	1	0	No
094	0	0	0	2	-	0	-	-	-
095	0	0	0	0	0	0	0	0	Yes
096	0	0	0	0	0	0	-	0	-
097	0	1	-	2	-	2	2	0	-
098	0	2	1	1	-	0	-	3	-
099	0	0	0	0	-	0	-	0	-
100	0	2	-	3	-	-	-	-	-
101	0	0	-	0	-	-	-	0	-
102	1	0	2	1	3	2	2	2	No
103	0	0	-	0	-	-	-	0	-
104	0	0	-	2	-	3	-	2	Yes
105	0	1	1	0	-	2	-	0	No
106	0	0	0	0	0	0	0	0	Yes
107	1	0	2	1	-	0	-	1	-
108	-	-	-	-	-	-	-	-	-
109	0	0	0	0	0	0	0	0	-
110	0	1	1	0	-	0	0	0	-
111	0	2	1	0	-	-	-	0	-
112	0	0	0	0	0	0	0	0	Yes
113	1	3	2	2	-	0	-	3	-
114	0	0	0	0	0	0	1	1	No
115	2	2	2	2	-	-	-	-	-

(continued)

TABLE A-3 (continued)

Plant No.	Staff Capabilities	Age Of Equipment	Spare Parts Inventory	Preventive Maintenance	Emergency Provisions	Backup Unit Provisions	Technical References	Housekeeping Practices	Auxiliary Power Source
116	0	0	-	0	-	0	-	0	-
117	0	-	2	0	-	-	-	0	-
118	1	0	1	1	-	0	-	-	-
119	-	-	-	-	-	-	-	-	-
120	0	1	0	0	-	0	0	0	-

Rating	Interpretation
3	Plant is deficient in this area. Capability is nonexistent. Considerable problems result.
2	Plant may be deficient in this area. Capability is inadequate. Some problems result.
1	Plant may be deficient in this area. Capability is marginally adequate. Little or no problems result.
0	No apparent deficiencies exist. Capability appears adequate. No problems are apparent.

TABLE B-1. PLANT EVALUATION SUMMARY

PLANT NO. 042

PLANT TYPE: Aerated Lagoon

DESIGN FLOW: 0.55 MGD

ACTUAL FLOW: 0.40 MGD

YEAR PLANT BUILT: 1969

YEAR OF MOST RECENT UPGRADE:

PLANT PERFORMANCE:

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 2.e.	Disinfection	3
2	Design 4.b.3.	Flow Proportioning to Units	3
3	Operation 2.b.	Process Control Testing	3
4	Operation 4.a.	O&M Manual - Adequacy	2
5	Operation 3.a	Operator Application of Concepts and Testing to Process Control	2
6	Design 4.f.	Laboratory Space and Equipment	2
7	Design 2.c.2.	Process Controlability	2
8	Design 1.c.	Plant Loading - Industrial	2
9	Design 1.b.	Plant Loading - Hydraulic	2
10	Administration 2.a.2	Manpower - Plant Coverage	2

TABLE B-2. PLANT EVALUATION SUMMARY

PLANT NO. 037

PLANT TYPE:	Extended Aeration
DESIGN FLOW:	0.5 MGD
ACTUAL FLOW:	0.5 MGD
YEAR PLANT BUILT:	1965
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	3
2	Operation 3.b.	Technical Guidance	3
3	Operation 4.a.	O&M Manual Adequacy	3
4	Design 2.c.3.	Unit Design Adequacy-Secondary-Aerator	3
5	Design 2.f.	Sludge Wasting and Return	3
6	Design 1.b.	Plant Loading - Hydraulic	2
7	Design 2.c.2.	Process Controlability	2
8	Design 2.e.	Disinfection	2
9	Operation 1.b.2.	Training	2
10	Operation 2.a.	Performance Monitoring	2

TABLE B-3. PLANT EVALUATION SUMMARY

PLANT NO. 102

PLANT TYPE:	Contact-Stabilization
DESIGN FLOW:	0.125 MGD
ACTUAL FLOW:	
YEAR PLANT BUILT:	1969
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Administration 1.b.	Plant Administrators - Familiarity with Plant Needs	3
2	Operation 1.b.2.	Training	3
3	Operation 2.b.	Process Control Testing	3
4	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	3
5	Operation 1.c.	Sewage Treatment Understanding	2
6	Operation 2.a.	Performance Monitoring	2
7	Operation 1.b.1	Level of Certification	2
8	Administration 1.a.	Plant Administrators - Policies	2
9	Maintenance 2.b.	References Available	2
10	Design 1.f.	Plant Loading - Infiltration/Inflow	2

TABLE B-4. PLANT EVALUATION SUMMARY

PLANT NO. 005

PLANT TYPE:	Extended Aeration
DESIGN FLOW:	0.25 MGD
ACTUAL FLOW:	0.15 MGD
YEAR PLANT BUILT:	1970
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 2.g.	Sludge Treatment	3
2	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	3
3	Operation 1.b.2.	Training	2
4	Operation 2.b.	Process Control Testing	2
5	Operation 1.c.	Sewage Treatment Understanding	2
6	Administration 3.a.	Insufficient Funding	2
7	Operation 4.a.	O&M Manual Adequacy	2
8	Administration 1.b.	Plant Administrators - Familiarity with Plant Needs	2
9	Design 1.f.	Plant Loading - Infiltration/Inflow	2
10	Design 4.e.	Lack of Standby Units For Key Equipment	2

TABLE B-5. PLANT EVALUATION SUMMARY

PLANT NO. 086

PLANT TYPE:	Contact-Stabilization
DESIGN FLOW:	0.5 mgd
ACTUAL FLOW:	0.39 MGD
YEAR PLANT BUILT:	1963
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Maintenance 2.a.	Preventive Maintenance - Lack of Program	3
2	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	3
3	Administration 2.a1	Manpower - Number	3
4	Operation 2.b.	Process Control Testing	2
5	Operation 1.c.	Sewage Treatment Understanding	2
6	Operation 4.a.	O&M Manual Adequacy	2
7	Maintenance 2.c.	Spare Parts Inventory	2
8	Design 4.f.	Laboratory Space and Equipment	2
9	Administration 2.a.2	Manpower - Plant Coverage	2
10	Design 1.f.	Pland Loading - Infiltration/Inflow	2

TABLE B-6. PLANT EVALUATION SUMMARY

PLANT NO. 032

PLANT TYPE:	Conventional Activated Sludge
DESIGN FLOW:	4.0 MGD
ACTUAL FLOW:	3.1 MGD
YEAR PLANT BUILT:	1973
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 1.a.	Plant Loading - Organic	2
2	Operation 3.b.	Technical Guidance	2
3	Operation 2.b.	Process Control Testing	2
4	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	2
5	Operation 1.c.	Sewage Treatment Understanding	1
6	Design 1.f.	Plant Loading - Infiltration/Inflow	1
7	Design 1.c.	Plant Loading - Industrial	1
8	Maintenance 1.d.	Manpower	1
9	Operation 4.b.	O&M Manual - Use by Operators	1
10	Administration 2.b.1	Motivation	1

TABLE B-7. PLANT EVALUATION SUMMARY

PLANT NO. 059

PLANT TYPE:	Contact-Stabilization
DESIGN FLOW:	12.0 MGD
ACTUAL FLOW:	9.2 MGD
YEAR PLANT BUILT:	1933
YEAR OF MOST RECENT UPGRADE:	1970
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 2.g.	Sludge Treatment	3
2	Design 2.b.	Unit Design Adequacy - Primary	3
3	Design 4.b.2.	Submerged Weirs	3
4	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	2
5	Design 2.e.	Disinfection	2
6	Design 4.b.1	Flow Backup	2
7	Maintenance 1.d.	Manpower	1
8	Operation 1.c.	Sewage Treatment Understanding	1
9	Design 1.f.	Plant Loading - Infiltration/Inflow	1
10	Design 3.b.	Alternate Power Source	1

TABLE B-8. PLANT EVALUATION SUMMARY

PLANT NO. 024

PLANT TYPE:	Conventional Activated Sludge
DESIGN FLOW:	1.30 MGD
ACTUAL FLOW:	1.30 MGD
YEAR PLANT BUILT:	1952
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 1.a.	Plant Loading - Organic	3
2	Design 1.c.	Plant Loading - Industrial	3
3	Design 1.f.	Plant Loading - Infiltration/Inflow	3
4	Design 2.c.3.	Unit Design Adequacy - Secondary - Aerator	3
5	Operation 4.a.	O&M Manual Adequacy	3
6	Maintenance 1.b.	Equipment Age	2
7	Operation 2.a.	Performance Monitoring	2
8	Operation 2.b.	Process Control Testing	2
9	Operation 3.a.	Operator Application to Concepts and Testing to Process Control	2
10	Design 4.f.	Laboratory Space and Equipment	2

TABLE B-9. PLANT EVALUATION SUMMARY

PLANT NO. 038

PLANT TYPE:	Trickling Filter
DESIGN FLOW:	7.0 MGD
ACTUAL FLOW:	4.6 MGD
YEAR PLANT BUILT:	1936
YEAR OF MOST RECENT UPGRADE:	1969
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 1.a.	Plant Loading - Organic	2
2	Design 1.c.	Plant Loading - Industrial	2
3	Design 3.c.	Plant Location	2
4	Design 2.c.2.	Process Controlability	1
5	Operation 4.a.	O&M Manual Adequacy	1
6	Operation 2.b.	Process Control Testing	1
7	Maintenance 2.b.1	References Available	1
8	Administration 2.b.1	Motivation	1
9	Administration 2.c.	Productivity	1
10	Design 3.b.	Alternate Power Source	1

TABLE B-10. PLANT EVALUATION SUMMARY

PLANT NO. 093

PLANT TYPE:	Conventional Activated Sludge & Contact Stabilization
DESIGN FLOW:	10.0 MGD
ACTUAL FLOW:	5.9 MGD
YEAR PLANT BUILT:	1965
YEAR OF MOST RECENT UPGRADE:	1976
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 2.g.	Sludge Treatment	2
2	Design 2.c.3.	Unit Design Adequacy - Aerator	2
3	Design 2.e.	Disinfection	2
4	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	2
5	Maintenance 2.b.	References Available	2
6	Operation 4.a.	O&M Manual Adequacy	2
7	Operation 1.b.2	Training	1
8	Design 1.f.	Plant Loading - Infiltration/Inflow	1
9	Operation 5.b.	Shift Staffing Adequacy	1
10	Maintenance 2.c.	Spare Parts Inventory	1

TABLE B-11. PLANT EVALUATION SUMMARY

PLANT NO. 082

PLANT TYPE:	Contact Stabilization
DESIGN FLOW:	0.95 MGD
ACTUAL FLOW:	1.0 MGD
YEAR PLANT BUILT:	1961
YEAR OF MOST RECENT UPGRADE:	1970
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 2.f.	Sludge Wasting and Return	3
2	Design 2.b.	Unit Design Adequacy - Primary	3
3	Operation 2.b.	Process Control Testing	3
4	Operation 4.a.	O&M Manual - Adequacy	3
5	Design 1.b.	Plant Loading - Hydraulic	2
6	Design 1.c.	Plant Loading - Industrial	2
7	Design 1.g.	Return Process Streams	2
8	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	2
9	Operation 3.b.	Technical Guidance	2
10	Design 3.b.	Alternate Power Source	1

TABLE B-12. PLANT EVALUATION SUMMARY

PLANT NO. 006

PLANT TYPE:	Conventional Activated Sludge
DESIGN FLOW:	0.5 MGD
ACTUAL FLOW:	0.55 MGD
YEAR PLANT BUILT:	1947
YEAR OF MOST RECENT UPGRADE:	1973
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Administrator 2.a.1	Plant Staff - Number	2
2	Maintenance 1.d.	Manpower	2
3	Operator 3.a.	Operator Application of Concepts and Testing to Process Control	2
4	Operation 1.c	Sewage Treatment Understanding	2
5	Administration 1.b.	Plant Administrators - Familiarity with Plant Needs	2
6	Operation 4.a.	O&M Manual - Adequacy	2
7	Design 2.e.	Disinfection	2
8	Operation 1.b.2.	Training	2
9	Design 4.e.	Lack of Standby Units for Key Equipment	2
10	Design 1.f.	Plant Loading - Infiltration/Inflow	2

TABLE B-13. PLANT EVALUATION SUMMARY

PLANT NO. 048

PLANT TYPE:	Complete Mix Activated Sludge
DESIGN FLOW:	3.0 MGD
ACTUAL FLOW:	4.0 MGD
YEAR PLANT BUILT:	1973
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 1.f	Infiltration/Inflow	3
2	Design 2.c.2	Process Controlability	3
3	Design 2.c.1	Secondary Process Flexibility	2
4	Design 2.f.	Sludge Wasting and Return	2
5	Operation 5.a.	Equipment Malfunction	2
6	Design 4.b.2	Submerged Weirs	2
7	Design 2.c.4	Unit Design Adequacy - Secondary-Clarifier	2
8	Design 2.c.3	Unit Design Adequacy - Secondary-Aerator	2
9	Design 4.c.	Unit Accessibility	1
10	Maintenance 3.b.	Critical Parts Procurement	1

TABLE B-14. PLANT EVALUATION SUMMARY

PLANT NO. 089

PLANT TYPE:	Contact-Stabilization
DESIGN FLOW:	0.6 MGD
ACTUAL FLOW:	0.37 MGD
YEAR PLANT BUILT:	1966
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	2
2	Operation 1.b.2.	Training	2
3	Design 1.c.	Plant Loading - Industrial	2
4	Design 1.f.	Plant Loading - Infiltration/Inflow	2
5	Operation 2.b.	Process Control Testing	1
6	Operation 1.c.	Sewage Treatment Understanding	1
7	Operation 2.a.	Performance Monitoring	1
8	Operation 3.b.	Technical Guidance	1
9	Operation 4.a.	O&M Manual - Adequacy	1
10	Design 2.c.1.	Secondary Process Flexibility	1

TABLE B-15. PLANT EVALUATION SUMMARY

PLANT NO. 095

PLANT TYPE:	Contact Stabilization
DESIGN FLOW:	0.35 MGD
ACTUAL FLOW:	0.30 MGD
YEAR PLANT BUILT:	1964
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 2.c.3.	Unit Design Adequacy - Secondary - Aerator	2
2	Design 1.f.	Plant Loading - Infiltration/Inflow	2
3	Design 2.c.1	Secondary Process Flexibility	2
4	Design 4.a.	Lack of Unit Bypass	2
5	Operation 4.a.	O&M Manual Adequacy	1
6	Design 1.c.	Plant Loading - Industrial	1
7	Design 4.d.1.	Process Automation - Monitoring	1
8	Design 4.d.2.	Process Automation - Control	1
9	Administration 2.a.2	Manpower - Plant Coverage	1
10			

TABLE B-16. PLANT EVALUATION SUMMARY

PLANT NO. 120

PLANT TYPE:	Conventional Activated Sludge (w/Roughing Filter)
DESIGN FLOW:	3.0 MGD
ACTUAL FLOW:	2.7 MGD
YEAR PLANT BUILT:	
YEAR OF MOST RECENT UPGRADE:	1970
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 1.c.	Plant Loading - Industrial	2
2	Design 1.a.	Plant Loading - Organic	2
3	Administration 2.c.	Productivity	2
4	Operation 3.a.	Operator Application of Concepts And Testing to Process Control	2
5	Administration 2.a.2	Manpower - Plant Coverage	1
6	Operation 1.b.2.	Training	1
7	Design 1.f.	Infiltration/Inflow	1
8	Operation 2.b.	Process Control Testing	1
9	Maintenance 1.d.	Manpower	1
10	Administration 2.b.1	Motivation	1

TABLE B-17. PLANT EVALUATION SUMMARY

PLANT NO. 034

PLANT TYPE:	Extended Aeration
DESIGN FLOW:	0.25 MGD
ACTUAL FLOW:	0.40 MGD
YEAR PLANT BUILT:	1963
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 1.b.	Hydraulic	3
2	Operation 3.a.	Operator Application of Concepts And Testing to Process Control	2
3	Design 1.f.	Infiltration/Inflow	2
4	Operation 2.b.	Process Control Testing	2
5	Administration 2.a.2	Manpower - Plant Coverage	2
6	Operation 2.a.	Performance Monitoring	2
7	Design 4.f.	Laboratory Space and Equipment	1
8	Operation 1.b.2.	Training	1
9	Operation 3.b.	Technical Guidance	1
10	Administration 2.d.	Personnel Turnover	1

TABLE B-18. PLANT EVALUATION SUMMARY

PLANT NO. 068

PLANT TYPE:	Activated Sludge - Aerator/Clarifier
DESIGN FLOW:	0.5 MGD
ACTUAL FLOW:	0.49
YEAR PLANT BUILT:	1949
YEAR OF MOST RECENT UPGRADE:	1969
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Operation 1.c.	Sewage Treatment Understanding	2
2	Operation 2.b.	Process Control Testing	2
3	Operation 3.a.	Operator Application of Concepts And Testing to Process Control	2
4	Design 4.c.	Unit Accessibility	2
5	Administration 3.a.	Insufficient Funding	2
6	Operation 2.a.	Performance Monitoring	2
7	Design 1.f.	Plant Loading - Infiltration/Inflow	2
8	Operation 4.a.	O&M Manual - Adequacy	2
9	Maintenance 2.a.	Lack of Program	1
10	Maintenance 1.c.	Scheduling and Recording	1

TABLE B-19. PLANT EVALUATION SUMMARY

PLANT NO. 071

PLANT TYPE:	Trickling Filter
DESIGN FLOW:	1.25 MGD
ACTUAL FLOW:	1.15 MGD
YEAR PLANT BUILT:	1961
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 1.d.	Plant Loading - Toxic	3
2	Design 1.f.	Plant Loading - Infiltration/Inflow	2
3	Design 4.f.	Laboratory Space and Equipment	2
4	Operation 3.a.	Operator Application of Concepts And Testing to Process Control	1
5	Operation 1.b.2.	Training	1
6	Design 4.e.	Lack of Stand-by Units For Key Equipment	1
7	Maintenance 1.b.	Equipment Age	1
8	Maintenance 2.c.	Spare Parts Inventory	1
9	Design 3.f.	Plant Inoperability Due to Weather	1
10			

TABLE B-20. PLANT EVALUATION SUMMARY

PLANT NO. 077

PLANT TYPE:	Trickling Filter/Bio-Discs
DESIGN FLOW:	1.75 MGD
ACTUAL FLOW:	1.2 MGD
YEAR PLANT BUILT:	1969
YEAR OF MOST RECENT UPGRADE:	1975
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 2.c.2.	Secondary Process Controlability	2
2	Design 1.f.	Infiltration/Inflow	2
3	Design 3.b.	Alternate Power Source	1
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TABLE B-21. PLANT EVALUATION SUMMARY

PLANT NO. 021

PLANT TYPE:	Extended Aeration
DESIGN FLOW:	1.25 MGD
ACTUAL FLOW:	0.88 MGD
YEAR PLANT BUILT:	1970
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	2
2	Design 4.f.	Laboratory Space and Equipment	2
3	Design 2.g.	Sludge Treatment	2
4	Operation 4.a.	O&M Manual - Adequacy	2
5	Operation 1.c.	Sewage Treatment Understanding	1
6	Design 1.b.	Plant Loading - Hydraulic	1
7	Design 1.c.	Plant Loading - Infiltration/Inflow	1
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TABLE B-22. PLANT EVALUATION SUMMARY

PLANT NO. 026

PLANT TYPE:	Activated Sludge
DESIGN FLOW:	8.5 MGD
ACTUAL FLOW:	7.5 MGD
YEAR PLANT BUILT:	1957
YEAR OF MOST RECENT UPGRADE:	1969
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 1.b.	Plant Loading - Hydraulic	3
2	Design 1.f.	Plant Loading - Infiltration/Inflow	2
3	Operation 2.b.	Process Control Testing	2
4	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	2
5	Operation 4.a.	O&M Manual - Adequacy	2
6	Design 2.b.	Unit Design Adequacy - Primary	2
7	Operation 3.b.	Technical Guidance	1
8	Administration 1.a.	Policies	1
9	Maintenance 2.c.	Spare Parts Inventory	1
10	Administration 2.c.	Productivity	1

TABLE B-23. PLANT EVALUATION SUMMARY

PLANT NO. 046

PLANT TYPE:	Extended Aeration
DESIGN FLOW:	0.21 MGD
ACTUAL FLOW:	0.24 MGD
YEAR PLANT BUILT:	1970
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Administration 2.a.1	Plant Staff - Number	3
2	Design 4.e.	Lack of Standby Units for Key Equipment	3
3	Maintenance 2.a	Preventive - Lack of Program	2
4	Maintenance 1.d.	Manpower	2
5	Maintenance 2.c.	Spare Parts Inventory	2
6	Maintenance 1.c.	Scheduling and Recording	2
7	Maintenance 1.a.	Housekeeping	2
8	Operation 2.b.	Process Control Testing	2
9	Design 1.f.	Plant Loading - Infiltration/Inflow	2
10	Operation 4.a.	O&M Manual - Adequacy	1

TABLE B-24. PLANT EVALUATION SUMMARY

PLANT NO. 114

PLANT TYPE:	Oxygen Activated Sludge
DESIGN FLOW:	14.0 MGD
ACTUAL FLOW:	10.7 MGD
YEAR PLANT BUILT:	1954
YEAR OF MOST RECENT UPGRADE:	1970
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 2.h.	Ultimate Sludge Disposal	2
2	Design 4.b.2	Submerged Weirs	1
3	Design 1.f.	Infiltration/Inflow	1
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TABLE B-25. PLANT EVALUATION SUMMARY

PLANT NO. 106

PLANT TYPE:	Extended Aeration
DESIGN FLOW:	7.0 MGD
ACTUAL FLOW:	3.1 MGD
YEAR PLANT BUILT:	1965
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 1.f.	Infiltration/Inflow	2
2	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	1
3	Operation 2.b.	Process Control Testing	1
4	Design 4.b.3	Flow Proportioning to Units	1
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TABLE B-26. PLANT EVALUATION SUMMARY

PLANT NO. 053

PLANT TYPE:	Conventional Activated Sludge
DESIGN FLOW:	3.0 MGD
ACTUAL FLOW:	2.2 MGD
YEAR PLANT BUILT:	1971
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 1.f.	Plant Loading - Infiltration/Inflow	3
2	Design 4.b.3.	Flow Proportioning to Units	3
3	Operation 4.a.	O&M Manual - Adequacy	3
4	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	2
5	Operation 2.b.	Process Control Testing	2
6	Design 2.g.	Sludge Treatment	2
7	Maintenance 2.c.	Spare Parts Inventory	2
8	Maintenance 3.b.	Critical Parts Procurement	2
9	Design 4.f.	Laboratory Space and Equipment	1
10			

TABLE B-27. PLANT EVALUATION SUMMARY

PLANT NO. 074

PLANT TYPE:	Trickling Filter
DESIGN FLOW:	0.89 MGD
ACTUAL FLOW:	0.7 MGD
YEAR PLANT BUILT:	
YEAR OF MOST RECENT UPGRADE:	1959
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 1.a.	Plant Loading - Organic	2
2	Design 1.c.	Plant Loading - Industrial	2
3	Design 4.b.3	Flow Proportioning to Units	2
4	Operation 5.a.	Equipment Malfunction	1
5	Maintenance 1.b.	Equipment Age	1
6	Maintenance 2.a.	Preventive Maintenance - Lack of Program	1
7	Operation 4.a.	O&M Manual - Adequacy	1
8	Maintenance 1.a.	Housekeeping	1
9			
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TABLE B-28. PLANT EVALUATION SUMMARY

PLANT NO. 083

PLANT TYPE:	Activated Sludge
DESIGN FLOW:	15 MGD
ACTUAL FLOW:	8.8 MGD
YEAR PLANT BUILT:	1956
YEAR OF MOST RECENT UPGRADE:	1974
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	2
2	Maintenance 2.c.	Spare Parts Inventory	2
3	Maintenance 2.a.	Preventive Maintenance-Lack of Program	1
4	Administration 2.b.2	Pay	1
5	Administration 2.d.	Personnel Turnover	1
6	Design 4.a.	Lack of Unit Bypass	1
7	Design 1.c.	Plant Loading - Industrial	1
8	Maintenance 3.b.	Critical Parts Procurement	1
9	Design 2.c.2	Secondary Process Controlability	1
10			

TABLE B-29. PLANT EVALUATION SUMMARY

PLANT NO. 066

PLANT TYPE:	Contact-Stabilization
DESIGN FLOW:	1.0 MGD
ACTUAL FLOW:	0.33 MGD
YEAR PLANT BUILT:	1969
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Design 1.f.	Plant Loading - Infiltration/Inflow	2
2	Design 1.a.	Plant Loading - Organic	2
3	Design 2.c.2.	Secondary Process Controlability	1
4	Design 2.g.	Sludge Treatment	1
5	Design 1.e.	Plant Loading - Seasonal Variation	1
6	Operation 2.b.	Process Control Testing	1
7	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	1
8	Operation 5.a.	Equipment Malfunction	1
9	Maintenance 3.b.	Critical Parts Procurement	1
10	Design 2.h.	Ultimate Sludge Disposal	1

TABLE B-30. PLANT EVALUATION SUMMARY

PLANT NO. 078

PLANT TYPE:	Extended Aeration (Oxidation Ditch)
DESIGN FLOW:	0.21 MGD
ACTUAL FLOW:	0.24 MGD
YEAR PLANT BUILT:	1970
YEAR OF MOST RECENT UPGRADE:	
PLANT PERFORMANCE:	

RANKING	TABLE REFERENCE	CAUSE	POINTS
1	Administration 3.a.	Insufficient Funding	3
2	Maintenance 1.d.	Manpower	3
3	Administration 2.a.1	Plant Staff - Number	3
4	Design 3.f.	Plant Inoperability Due to Weather	3
5	Operation 3.a.	Operator Application of Concepts and Testing to Process Control	2
6	Design 2.c.4.	Unit Design Adequacy - Secondary Clarifier	2
7	Maintenance 2.a.	Preventive - Lack of Program	2
8	Maintenance 1.a.	Housekeeping	2
9	Operation 1.b.2.	Training	2
10	Maintenance 2.c.	Spare Parts Inventory	2

TABLE C-1. LIST OF RECOMMENDATIONS FROM PRELIMINARY EVALUATION REPORTS

Plant Number	Recommendations
034	1. Upgrade sampling and analysis techniques.
	2. Prepare comprehensive O & M manual.
	3. Provide plant specific training for operating staff.
048	1. Upgrade plant capacity or reduce infiltration/inflow.
068	1. Improve chlorination of effluent.
	2. Reduce infiltration/inflow.
	3. Upgrade sampling and analysis techniques.
	4. Discontinue addition of lime to aeration tanks.
	5. Employ process control/laboratory technician.
	6. Prepare comprehensive O & M manual.
	7. Install auxiliary power supply and alarm system.
114	1. Prepare daily cleanup schedule.
	2. Modify analytical program to put more emphasis on process control.
037	1. Upgrade laboratory facilities.
	2. Upgrade training of personnel regarding analytical function.
	3. Expand wastewater parameters tested and process control.
086	1. Repair grit chamber and comminutor.
	2. Repair or replace sludge collection mechanism.
	3. Increase return sludge volume.
	4. Operate aeration stage blowers continuously.
	5. Establish systematic routine maintenance program.
	6. Improve quality control of laboratory work.
	7. Hire supervisory and maintenance personnel.
	8. Increase budget 20 percent.

(continued)

Plant Number	Recommendations
042	1. Increase substantially the operation and routine maintenance manpower. 2. Implement preventive maintenance program. 3. Prepare comprehensive O & M manual. 4. Upgrade laboratory program for adequate process control.
021	1. Prepare comprehensive O & M manual and train personnel in accordance with manual. 2. Upgrade laboratory capabilities for process control and performance monitoring using EPA approved procedures. 3. Conduct performance testing as required by NPDES permit. 4. Eliminate filamentous growth in activated sludge system.
046	1. Reduce infiltration/inflow. 2. Improve sampling procedures in accordance with provisions of NPDES permit. 3. Submit quarterly NPDES reports as required by regulatory agency. 4. Maintain full-time operating personnel. 5. Train plant staff in process control techniques. 6. Modify O & M manual to address unit processes and equipment not covered in present manual. 7. Maintain adequate spare parts inventory. 8. Increase budget to provide for a full-time plant operator.
006	1. Reduce floating material on final clarifier. 2. Repair chlorinators 3. Utilize lab data to optimize operating parameters. 4. Prepare comprehensive O & M manual. 5. Provide auxiliary power source and alarm system. 6. Employ a full-time superintendent.
005	1. Improve process control. 2. Upgrade training of staff. 3. Modify plant O & M manual. 4. Utilize one of two aeration tanks as an aerobic digester.
093	1. Reduce suspended solids in effluent through increased sludge wasting. 2. Decrease chlorine feed concentrations and improve mixing of chlorine and wastewater. 3. Hire two additional personnel and implement staffing schedule.

(continued)

Plant Number	Recommendations
083	1. Continue to optimize centrifuge performance. 2. Upgrade vacuum filter. 3. Expand spare parts inventory. 4. Increase and improve control of sludge wasting rate.
066	1. Optimize use of contact and stabilization tanks. 2. Improve control of F/M. 3. Provide additional sludge dewatering capacity. 4. Use approved chlorine residual test method. 5. Prepare comprehensive O & M manual.
071	1. Use BOD$_5$ method approved by EPA. 2. Install a standby power source.
053	1. Modify or replace grit chamber screw pumps. 2. Initiate process control testing. 3. Purchase apparatus for daily analysis of MLSS concentration. 4. Prepare comprehensive O & M manual. 5. Establish maintenance schedule. 6. Establish spare parts inventory. 7. Sewer Authority should develop separate budget for each plant under its control.
095	1. Keep F/M between 0.2 and 0.5 Kg BOD$_5$/day/KgMLSS. 2. Reduce infiltration/inflow in collection system. 3. Upgrade sampling and analysis procedures. 4. Determine cause of excessive coliform counts. 5. Prepare comprehensive O & M manual.
024	1. Conduct industrial waste survey. 2. Establish controlled discharge or pretreatment program for industries. 3. Prepare comprehensive O & M manual and train workers in accordance with manual. 4. Expand laboratory capabilities. 5. Perform regular process control analyses.
078	1. Modernize equipment. 2. Increase MLVSS until F/M is reduced to about 0.30 Kg BOD$_5$/d/Kg MLSS. 3. Upgrade process control by monitoring DO, SVI, F/M, MCRT, MLSS, and MLVSS. 4. Prepare comprehensive O & M manual. 5. Hire individual with treatment plant maintenance experience.

(continued)

Plant Number	Recommendations
077	1. Revise sampling according to NPDES permit requirements. 2. Operate biological facilities in series.
082	1. Improve sludge handling. 2. Remove sludge directly from aerobic digester to tank truck. 3. Prepare comprehensive O & M manual. 4. Sample effluent in accordance with provisions of NPDES permit. 5. Monitor process control parameters. 6. Initiate part-time non-daylight shift coverage.
089	1. Enforce pretreatment ordinance. 2. Submit quarterly monitoring reports to regulatory agency. 3. Adhere to NPDES sampling and analysis procedures. 4. Increase sludge wasting rate. 5. Train plant staff in theory of contact-stabilization system and process control techniques. 6. Initiate process control monitoring program. 7. Prepare supplement to O & M manual.
074	1. Improve routine maintenance procedures. 2. Increase staff size. 3. Prepare comprehensive O & M manual. 4. Add ferric chloride and polymer to effluent only when needed.
120	1. Collect final effluent BOD_5 samples prior to disinfection. 2. Monitor F/M and MCRT regularly for control of activated sludge system. 3. Improve final clarifier efficiency through maintaining increased MLSS levels, thus, enhancing flocculation and settling qualities. 4. Provide third shift operator. 5. Prepare for removal of NH_3-N at plant as required by NPDES permit after July 1, 1977.
102	1. Inform responsible officials of plant conditions and consequences if conditions are not improved. 2. Employ full-time operator, experienced in both operations and maintenance. 3. Provide additional training of present operator. 4. Prepare comprehensive O & M manual.

(continued)

Plant Number	Recommendations
102 (Cont'd)	5. Retain consultant to evaluate performance and process monitoring needs, laboratory equipment needs, and maintenance program needs. 6. Establish adequate spare parts inventory. 7. Improve "housekeeping" practices. 8. Obtain emergency maintenance equipment. 9. Establish a workable budget.
106	1. Select biological process control method and operate under conventional parameters. 2. Enclose thickener as planned to prevent freezing problems in winter. 3. Prepare a comprehensive O & M manual.
026	1. Prepare supplement to O & M manual. 2. Utilize F/M or MCRT techniques to control operation. 3. Employ two additional maintenance personnel. 4. Increase supplies of spare parts and hand tools. 5. Improve "housekeeping" practices. 6. Increase budget to offset increased costs.
032	1. Equalize loadings on treatment plant. 2. Eliminate infiltration sources. 3. Increase primary clarifier efficiency through chemical addition. 4. Operate tertiary filtration system according to design intent.
038	1. Enforce provisions of local pretreatment ordinance. 2. Prepare comprehensive O & M manual. 3. Revise sampling techniques to conform to NPDES permit.
059	1. Increase sludge wasting rate to achieve lower MLSS concentrations and F/M more in line with conventional parameters. 2. Provide additional weir length in primary clarifiers to reduce weir loadings. 3. Improve removal of skimmings from primary clarifiers. 4. Remove sludge collection mechanism from chlorine contact tank and install baffles to eliminate short-circuiting. 5. Examine methods of increasing capacity of sludge thickening stage.